Materials Engineering in Product Design & Manufacture

Materials & Methods

November, 1954

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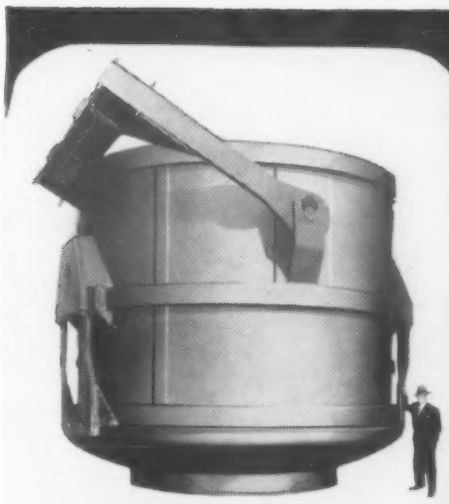

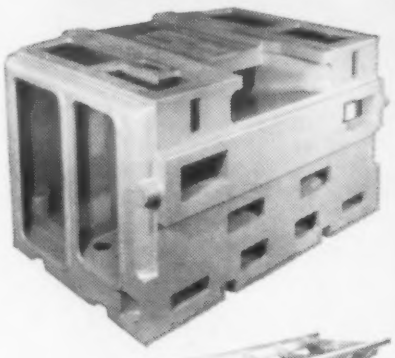

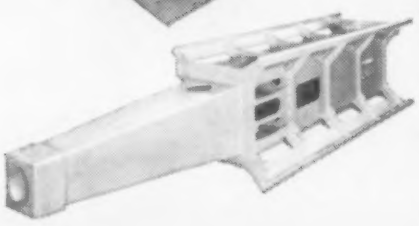

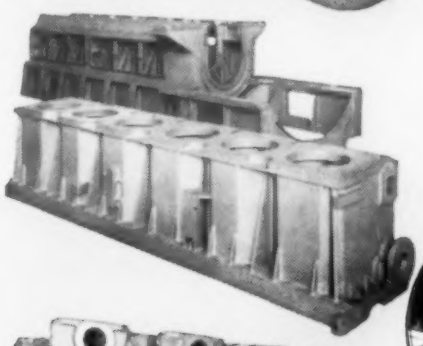

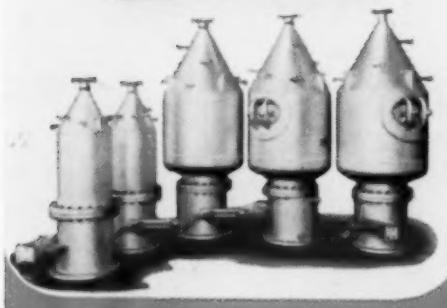

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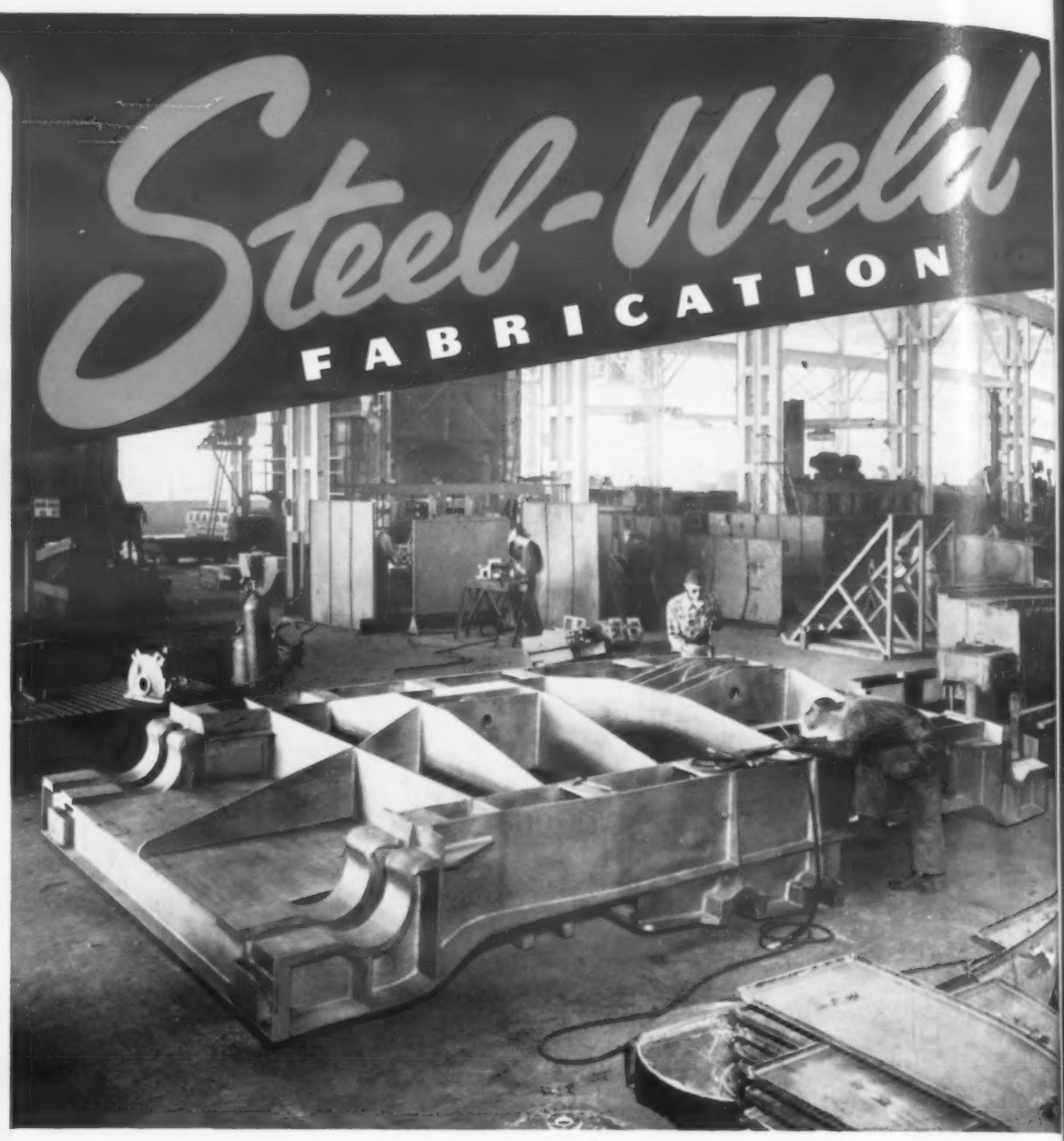

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Materials Engineering in Product Design & Manufacture

Materials & Methods.

NOVEMBER 1954 **VOL. 40, NO. 5**

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The Materials Outlook

MORE ASBESTOS

A large new asbestos mill recently started operations in Quebec. By 1956 it is expected to add 625,000 tons a year to the supply available on this side of the Iron Curtain - an increase of more than one-third over the present supply.

ZIRCONIUM ALLOYS SEEM LIMITED

Recent attempts to strengthen high-melting zirconium by means of binary additions of chromium, columbium, molybdenum, tantalum, tungsten and vanadium have failed to produce alloys any stronger than Inconel or Type 310 stainless in the 1800-2200 F temperature range. However, some of the stronger alloys may be useful as structural materials in atomic energy installations where their low neutron cross sections are advantageous.

PLASTICS TOOLING

Titanium aircraft parts are currently being hot formed at 1000 F by means of plastics dies. . . . A recent M&M survey of the plastics tooling picture shows that, although phenolics and glass-reinforced polyesters are still being widely used, the trend is definitely toward use of cast and glass-reinforced epoxy resins for a majority of applications despite their higher initial cost. (A two-part report on plastics tooling will start in next month's issue.)

DUCTILE ALUMINUM-IRON ALLOY

Vacuum melting has made possible the production of a ductile iron-aluminum alloy having excellent resistance to high-temperature oxidation. Excessive brittleness has previously blocked the development of satisfactory alloys in this system.

RAYON TIRE YARNS

The two companies producing so-called "super" rayon tire yarns of exceptionally high strength and fatigue life have been joined by a third important producer. Meanwhile, another large company not now in the field is reported to be developing a rayon-type yarn for tires and other industrial products.

TITANIUM BY NEW PROCESS

Plans for the first commercial production of titanium by a method other than the Kroll process have been announced. The

the Materials Outlook

process involves reduction of titanium tetrachloride by sodium instead of magnesium. The plant is expected to be in operation sometime in 1956 and will turn out at least 7500 tons a year (see p. 13).

MODIFIED HYDROFORMING

An aircraft manufacturer is reported to be experimenting with a forming process akin to hydroforming in which a neoprene blanket is used as the female die. Rapid inflation and deflation of the bladder provides a series of hammer-like blows during the forming operation.

NYLON AND CREEP

Nylon has been so broadly accepted as an industrial material that many designers have been considerably surprised to find adequate creep data lacking. Data recently presented to the ASTM seems to fill this gap. Now it seems possible that creep data may not be so important in the future, since irradiation seems to largely eliminate creep in nylon. However, irradiated nylon may prove too brittle for most idustrial uses.

MATERIALS SPECIFICATIONS

Among the materials covered by specifications now being developed by ASTM committees are hot dip zinc coatings on fabricated products; clad steel strip for radio tubes and incandescent lamps; tin-coated copper sheets; copper-impregnated metal powder parts; and metal powder filter materials.

LOW-COST TIN-ZINC PLATE

Steel can now be provided with a solderable zinc alloy plate at a price only slightly greater than that of an ordinary zinc plate. The "zincaloy" plating bath is said to combine conventional zinc and tin plating solutions in a new way.

NEW MILD STEEL WELDING PROCESS

The advantages of inert-arc consumable electrode welding can now be realized with mild steel. A new process combines specially coated mild steel wire, argon gas shield and straight polarity, together with improvements in standard welding equipment, to give high-quality welds at higher speed and lower cost compared with other manual and semi-automatic inert gas methods.

CERAMIC-COATED ALUMINUM

Ceramic-coated aluminum sheet is now available. Its combination of light weight, corrosion resistance and refractory qualities is expected to be particularly useful in aircraft.

DESIGNING WITH ALUMINUM

This is one of a series of information sheets which discuss the properties of aluminum and its alloys with relation to design. Extra or missing copies of the series will be supplied on request. Address: Advertising Department, Kaiser Aluminum & Chemical Sales, Inc., 1924 Broadway, Oakland 12, California.

NO. 8

CHOOSING A WROUGHT ALLOY

NEW RESEARCH DATA SHOWS ALUMINUM PROVIDES REDUCED HEAT AND FRICTION LOSSES

THE PROBLEM of selecting the most suitable aluminum wrought alloy and temper for a particular application can be a bewildering task for one not thoroughly familiar with all of the possibilities.

Although only about two dozen out of the list of nearly a hundred wrought alloys recognized by the Aluminum Association are in fairly regular use, each of them is available in a variety of cold worked or heat treated conditions.

Wrought alloys are available in three major classes of mill products: 1) sheet and plate; 2) rod, bar and wire; 3) extrusions. They are generally used in one of these forms or as forgings, in which case the forging blank is ordinarily produced from one of the standard mill products.

All of these alloys are not available in all four forms and it is usually possible to halve the list of alloys to be considered on the basis of the type of product involved. (Table I indicates the forms in which the various alloys may be obtained.)

Mechanical Properties Requirements

Every design places certain minimum requirements on the mechanical properties of the material from which it is fabricated. Thus, specified values of one or more of the following: yield strength, ultimate strength, per cent elongation, shearing strength, bearing strength, endurance limit and hardness, will automatically eliminate certain alloys and tempers from consideration.

Because the different methods by which wrought alloys are produced result in different amounts of plastic working of the metal, a given alloy may exhibit slightly different typical strengths in different forms.

The designer will recognize, of course, that mechanical properties differ widely among the various alloys available. Therefore, he must often find a single suitable alloy with the best combination of the various properties. To aid the designer, we have prepared typical mechanical and physical property tables on the various alloys. These tables may be obtained by writing to: Kaiser Aluminum & Chemical Sales, Inc., Industrial Service Division, 51176 Kaiser Building, Oakland 12, Calif.

If the design has not reached an advanced stage it may sometimes be altered to compensate for a deficiency in one aspect of a material having otherwise desirable characteristics. Sound engineering judgment is the only guide at this point.

Of equal importance is the ability of the material to retain its properties in the environment to which it will be exposed in service. In general, it may be said that alloys 1100 (2S) and 3003 (3S) are most corrosion resistant, followed closely (even exceeded in some environments) by the 5000 and 6000 series. Least resistant of all are the 2000 and 7000 series. (The reader is referred to No. 4 of this series "Designing with Aluminum" for a more detailed discussion of the corrosion resistance of aluminum alloys.)

TABLE I Alloy Availability

Alloy Designation				Rolled or Rolled & Drawn							Extrusions						Forgings
New	Old	Sheet	Plate	Round Drawn Wire	Rivet Wire & Rod	Screw Machine Stock	Rolled & C.F. Rod	Welding Wire	Round Forge Stock	Hex Wire & Bar	Rod	Bar	Solid Shapes	Tube & Pipe	Hollow Shapes	Drawn Tubes	
	EC			A							S	S	S	S	S		
1100	2S	A	A	A	A		S	S	A								A
2011	11S			A		A	A		S	A							A
2014	14S	A	A	A			S		A		A	A	A	A			A
2017	17S			A	A	A	A		A	A							A(6)
2018	18S								A								A(7)
2024	24S	A	A	A	A		A			A	A	A	A	A			
2025	25S								A								A
2117	A17S				A												
2218	B18S								A								A(7)
3003	3S	A	A								S(3)	S	S	S	S		
3004	4S	A	A													S	
4032	32S								A								A(7)
4043	43S							S									
5005	K15S	A	A														
5050	50S	A	A													S	
5052	52S	A	A	A			S									S	
5056	56S			A	A												
L5083	LK183		A(2)								S(4)	S	S	S			
5086	K186	A	A														
5357	K157	A(1)															
6053	53S										S(5)	S	S	S	S		
6061	61S	A	A	A	S		S		A		A	A	A	A	A	A	A
6062	62S										A	A	A	A	A		
6063	63S										A	A	A	A	A		
6151	A51S								A								A
7075	75S	A	A								A	A	A	A			A

Notes: A = Available. S = Special Inquiry.
(1) Special purpose alloy. Bright finish alloy used for decorative purposes only. Strength comparable to 3003 or 5005. Higher cost justified only when appearance is of maximum importance.
(2) High strength alloy. Used for heavy weldments where strength greater than 5086 is desired.
(3) Largely replaced by 6063.
(4) Structural members to be assembled by welding. Strength greater than 6061-0 or T4. Less than 6061-T6.
(5) Obsolescent alloy, generally replaced by 6061, 6062 or 6063.
(6) Largely replaced by 2014.
(7) High temperature service. Internal combustion engine pistons, etc.

Appearance, Ease of Operation, Cost

Having narrowed the choice of alloy and temper to those which will provide adequate strength and corrosion resistance, the final selection must be made on the basis of three other factors which are somewhat inter-related. They involve the appearance, suitability for intended method of manufacture and the cost.

Obviously, appearance of the finished product will not be a factor in all cases, but in some it may be paramount. If appearance is important, the ability of the material to respond to chemical or mechanical polishing must be considered. The color after anodiz-

PLEASE TURN TO NEXT PAGE ➡

ing depends on the nature and the quantity of alloying elements present.

The brightest and clearest surface available is that of 5357 (K157) which is used for light reflectors and for decorative trim in much the same manner as stainless steel and chrome plating. Only slightly less clear are alloys 5005 (K155), 5050 (50S) and 6063 (63S). Alloys containing manganese (3000 series) tend to show a yellowish color in the anodized coating while those containing sizeable amounts of magnesium exhibit a brownish-grey color. The 2000 series of alloys (containing copper) also yield dark anodized coatings unless used in clad form.

Matching Colors

One very important aspect of this problem which is too often overlooked is that of matching colors in different types of products.

As an example, it is usual practice to make the structural frame of a storm door from 6063 (63S) extrusions. The panels and/or kick plates do not require a strong alloy and it would be most uneconomical to use 6061 (61S) sheet for this purpose, and even if used it would be very slightly darker in color. While 3003 (3S) has adequate strength its color would be noticeably darker than that of the 6063 frame. The logical choice would be 5005 (K155) which matches the 6063 very nicely in color and the 3003 in strength and cost.

If cast alloys are involved in the finished product the problem of color matching becomes even more critical, since many of the casting alloys contain a high percentage of silicon which anodizes to a dark grey color. And, if parts are to be assembled by welding, care also must be shown in the choice of welding wire. Even when the welding wire is of the same alloy as the metal being welded, the bead is apt to be noticeable after polishing and anodizing.

Suitability for Production

In checking the suitability of the metal for the intended method of manufacture the engineer must answer questions of the following nature. 1) Can the alloy be formed easily? 2) Will it machine freely? 3) Is it weldable by shielded metal arc? Or shielded tungsten arc, gas welding, resistance welding? 4) Can it be brazed, soldered?

TABLE III Relative Fabrication Rating

Alloy and Temper	Cold Work	Suitability for		Welding		
		Machining	Brazing	Arc	Gas	Resistance
1100-0	E+	G	E	E	E	E
1100-H18	G−	G	E	E	E	E
3003-0	E+	G	E	E	E	E
3003-H18	F+	G	E	E	E	E
3004-0	E+	G	—	E	G	E
3004-H38	F+	G	—	E	G	E
2011-T3	F−	E	NS	P	P	G
2011-T8	P	E	NS	P	P	G
2014-T4	F	E	NS	F	P	P
2014-T6	F−	E	NS	F	P	P
Clad 2014-T4	F	E	NS	F	P	P
Clad 2014-T6	F−	E	NS	F	P	P
2017-0	E	G	NS	P	P	F
2017-T4	F	E	NS	P	P	F
2117-T4	G−	E	NS	P	P	F
2018-T61	—	E	NS	P	P	P
2024-0	E	G	NS	P	P	F
2024-T3	F−	E	NS	P	P	G
2024-T36	P+	E	NS	P	P	G
Clad 2024-T3	F	E	NS	P	P	E
Clad 2024-T36	F−	E	NS	P	P	E
2025-T6	—	G	NS	P	P	P
4032-T6	—	F	NS	P	P	P
5050-0	E+	G	G	E	E	E
5050-H38	F+	G	G	E	E	E
6151-T6	—	G	E	E	E	E
5052-0	E+	G	F	E	G	E
5052-H38	F+	G	F	E	G	E
5086-0	E	G	NS	G	—	—
5086-H36	F	G	NS	G	—	—
6053-T4	G−	G	E	E	E	E
6053-T6	F+	G	E	E	E	E
5056-0	E	G	—	—	—	—
5056-H38	G−	G	—	—	—	—
6061-0	E	G	E	E	E	E
6061-T4	G	G	E	E	E	E
6061-T6	G−	G	E	E	E	E
6063-T5	G−	G	E	E	E	E
6063-T6	F+	G	E	E	E	E
7075-0	E	G	NS	F	P	F
7075-T6	P	E	NS	F	P	G

These ratings are relative for aluminum alloys and should not be used for comparing aluminum with other metals.
E = Excellent, G = Good, F = Fair, P = Poor, N.S. = Not Suitable.

For example consider a deep drawn part requiring good corrosion resistance with a yield strength in excess of 35,000 psi. Here are four possibilities:

5052 - H36 . . . YP=35,000
3004 - H38 . . . YP=36,000
5052 - H38 . . . YP=37,000
Clad 6061 - T6 . . . YP=37,000

The 3004 alloy will probably not qualify because its corrosion resistance is less than the others. Table III shows that 5052 is not very suitable for cold working in the harder tempers. On the other hand, clad 6061 is excellent for forming in the O temper. The part might also be deep drawn after solution heat treating (W condition) and precipitation-hardened to the T6 condition after forming. If the required draw were not too deep it might be possible in 5052-H36 and the resulting savings in heat treating costs would make it worth investigating.

Material Costs

Most designers find it necessary to keep the cost of their finished products to the lowest possible figure. In order to accomplish this it is necessary to consider the choice of an alloy early in the design, because the cost per pound of metal does not tell the entire story. In the case of a welded pressure vessel, alloy 5086 (K186) costs approximately 1.3 times as much per pound as alloy 3003 (3S) yet its allowable strength is 2.6 times as great. The result is that much less material is needed and the final material cost of the more expensive (per pound) alloy is only one-half as great.

Cost in Production

Similarly, cost must be considered in relation to method of manufacture. Suppose that a requirement exists for a screw machine part to be made from 1.5 in. round rod, and that the mechanical properties of 1100-F (2S-F) are adequate. The 1100 alloy would cost less per pound, yet 2011-T3 (11S-T3) would probably be a much more economical choice because of the greater ease with which it could be machined.

It is difficult to give cost data upon which to base comparisons of the sort shown above since the price per pound of a given alloy is a function of many things: 1) the amount of work done in reducing it to the desired gauge, 2) the quantity ordered at one time, 3) the need for special tolerances, among others. Comparisons of the kind made here require an exact knowledge of the sizes and quantities of material involved and the availability of a complete price book.

More detailed assistance with design, alloy selection and fabrication procedures are obtainable through the Kaiser Aluminum sales office listed in your telephone directory, or through one of our many distributors. Kaiser Aluminum & Chemical Sales, Inc. *General Sales Office:* Palmolive Bldg., Chicago 11, Ill.; *Executive Office:* Kaiser Bldg., Oakland 12, California.

One point of view

The need for engineers

Recently much has been published about the shortage of engineers in this country. Usually such items wind up with a comparison of engineering education in this country and in Russia. In seeking an answer to the problem those responsible for developing programs to recruit engineers seem to overlook one highly essential factor. Engineering careers should be made to appear attractive to prospective young men and women.

When one stops to consider, engineering can be extremely interesting and highly satisfying. Many developments now—as in the past—have all of the elements of the most imaginative drama. The trouble is many engineering achievements are never talked about in such a way as to catch the imagination of impressionable young people.

Today every field is obliged to recognize that competition is intense for the minds and attentions of all humans. There is strong competition among all communications media; among entertainment media; and among careers.

Today it seems that most of our young people start growing up with a desire to be in the field of entertainment. They want to be actors, musicians, or even disk jockeys on radio. What seems to be sought is fame and recognition and money. To the outsider, most of these careers offer all of these things quickly and with very little effort.

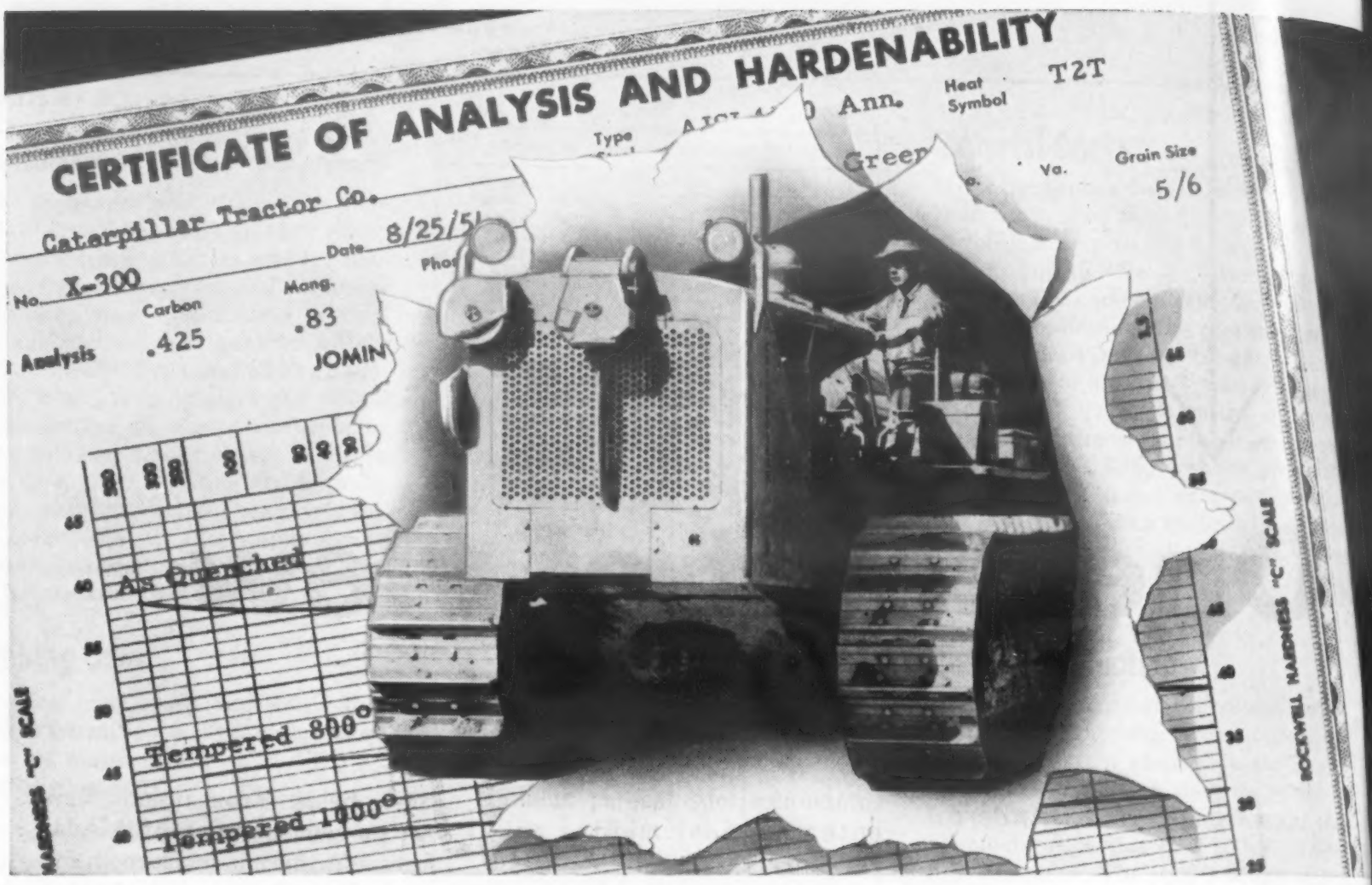
On the other hand, most young people look at engineering as something which offers little but dreariness and hard work. Mathematics, an essential to any engineering career, is difficult to understand and requires much study. It is much easier to study history, philosophy or some other subject which can be absorbed by merely reading or listening to a professor.

No simple solution seems to offer itself. Possibly the committees concerned with developing scientific and engineering manpower should engage in some long range educational programs designed to glamorize these fields. From time to time we see some attempts of this nature, but there is much room for improvement.

Too, individual companies whose future depends upon a constant supply of engineers should seek methods by which engineers responsible for outstanding developments can be given public recognition. Some companies already are taking some steps in this direction by encouraging their engineers to prepare technical articles and present papers about their work. However, this only goes part way.

A certain number of youngsters will always be interested in science and engineering. It appears that as our civilization moves ahead, the number needed will multiply. Thus we must encourage many more to enter these fields than would naturally lean toward them. To do so will require much more imagination and positive action than has been shown up to the present time.

J. C. Du Mond



Caterpillar® quality control inspires Ryerson certification

It was 1935—Caterpillar pioneering in quality control—was concerned about the uniform quality of alloy steels from warehouse stock.

Ryerson wished to serve its customers in the best possible manner. We sent our metallurgists to Caterpillar and asked them what could be done that wasn't being done.

Caterpillar pointed out that in the heat treatment of parts there can be as much difference in behavior between two mill heats of the *same* type composition as between two heats of *different* type composition. To emphasize this fact, they cited a statement in the AISI Manual that it would be false and misleading to assume all steels of a given composition are the same.

Ryerson accepted the challenge and began laying the groundwork for a quality control program which would include—1. selecting mill heats, 2. spark testing and carefully segregating every heat, 3. identifying each heat by heat symbol, 4. color marking for AISI number, 5. testing for hardenability in our own laboratory, 6. interpreting hardenability, 7. final inspection before shipment, 8. furnishing Certificate of analysis and guide to heat treatment.

After two years of preparation—we announced the Ryerson Certified Alloy Steel Plan in 1937. And now—not only Caterpillar but all other alloy steel users can buy high uniform quality alloys from Ryerson warehouse stocks with complete confidence. The plan takes time and money but has been helpful to Caterpillar—and we believe—even more helpful to companies without the elaborate testing facilities of Caterpillar Tractor Co.

It just happens that Ryerson is one of four companies that have been serving Caterpillar since their founding—so we are particularly happy to tell this story of progress in quality control—inspired by Caterpillar on this, their 50th anniversary of service to America and to the world.

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by W. L. WROTEN,

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● IN ADDITION to its usual role in refractory applications bonded silicon carbide has been used for several years as a replacement for metals (see Materials & Methods, Nov. 1951). A new version, silicon-nitride-bonded silicon carbide has been developed by The Carborundum Co. This material called Refrax promises to extend the field of application of silicon carbide.

Refrax has a number of points of superiority over the regular grades of bonded silicon carbide. It has greater heat shock resistance, greater load carrying ability at high temperatures and somewhat superior thermal conductivity. Further it can be produced in intricate shapes to accuracies of ± 0.005 in/in. with or without external or internal threads.

Properties

To give some idea of the relationship between the new silicon-nitride-bonded silicon carbide and other more common refractories, characteristic properties are given in a table. The density is about the same as fused alumina and somewhat greater than fireclay. The thermal conductivity is ten times that of fireclay and somewhat greater than the regular bonded silicon carbide. The coefficient of thermal expansion and the specific heat are roughly the same as fireclay.

The superiority of this new material, however, is shown more clearly in its high temperature strength. At 2450 F, Refrax has a modulus of rupture of 5600 psi compared with 2000 for regular bonded silicon carbide, 200 for fused alumina and 110 for fireclay.

Since silicon-nitride-bonded silicon carbide will be expected to compete with the heat resisting alloys in high temperature applications, some comparisons are interesting. The density of the new material is about 40% of that of the chromium-nickel stainless steels and the thermal conductivity is about 70% except at higher temperatures, where it is still closer. With a coefficient of expansion only ¼ that of chromium-nickel stainless steels and only 37% of those of the straight high chromium steels, the problems of high temperature expansion are somewhat less acute. It is not pos-

Silicon-Nitride-Bonded Silicon Carbide Compared to Other Refractories

Property	Materials			
	Silicon Nitride Bonded Silicon Carbide	Regular Bonded Silicon Carbide	Low Silica Fused Alumina	Fireclay
Density, lb/cu in.	0.103	0.092	0.104	0.07–0.09
Thermal Cond., Btu/hr/sq ft/in./°F at 2200 F	114	109	24	11.5
Coef of Exp per °F: (77 to 2550 F)	2.7 x 10^{-6}(a)	2.4 x 10^{-6}	4.1 x 10^{-6}	3.3 x 10^{-6}
Mean Spec. Ht, Btu/lb/°F; (32 to 2550 F)	0.28	0.28	—	0.27
Porosity, %	6.0	13.2	21.9	—
Mod of Rupture at 2460 F, psi	5600(b)	2000	200	110
2730 F Load Test at 25 lb/sq in.—Contraction Cold, %	0.0	0.1	0.5	14–18

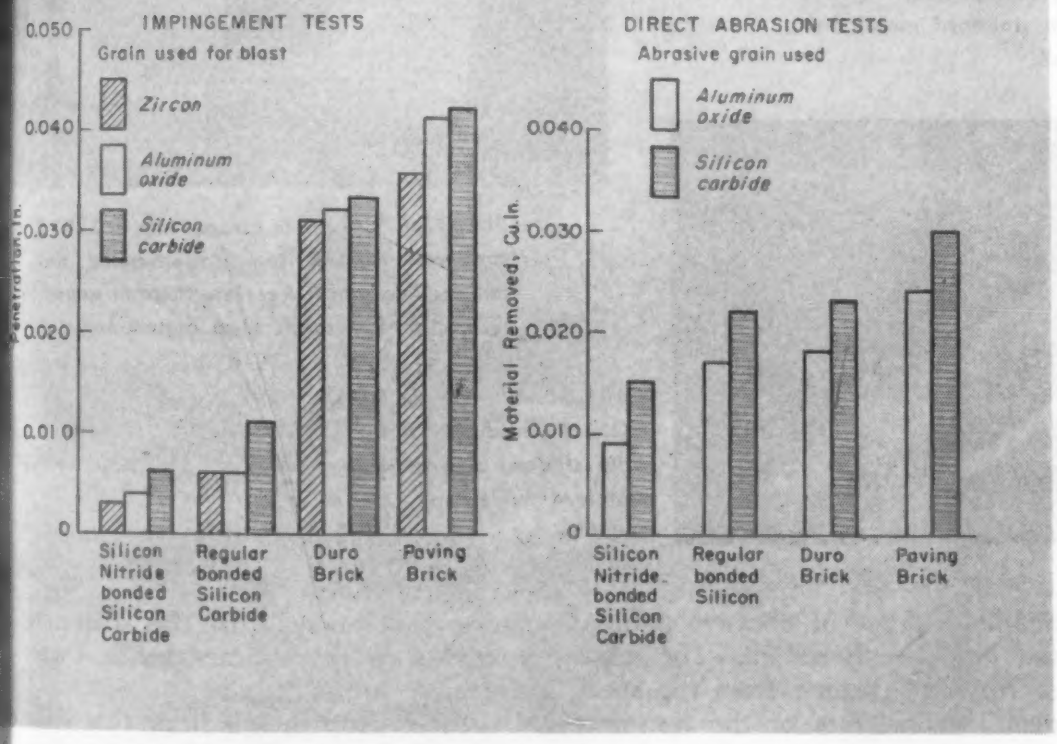
NOTES:

(a) Additional Thermal Expansion Data

77— 390 F	*1.81 x 10^{-6}*
77— 750 F	*2.09 x 10^{-6}*
77—1110 F	*2.26 x 10^{-6}*
77—1470 F	*2.38 x 10^{-6}*
77—1830 F	*2.48 x 10^{-6}*
77—2280 F	*2.61 x 10^{-6}*

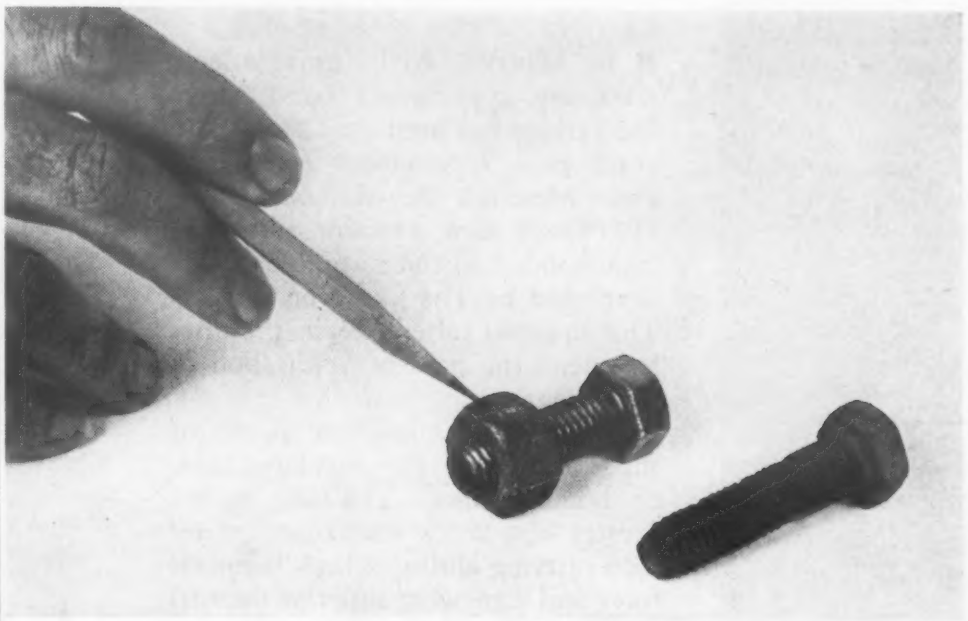
(b) Additional Modulus of Rupture Data—psi

77 F	*5500*
1290 F	*5500*
1830 F	*7000*
2730 F	*3000*

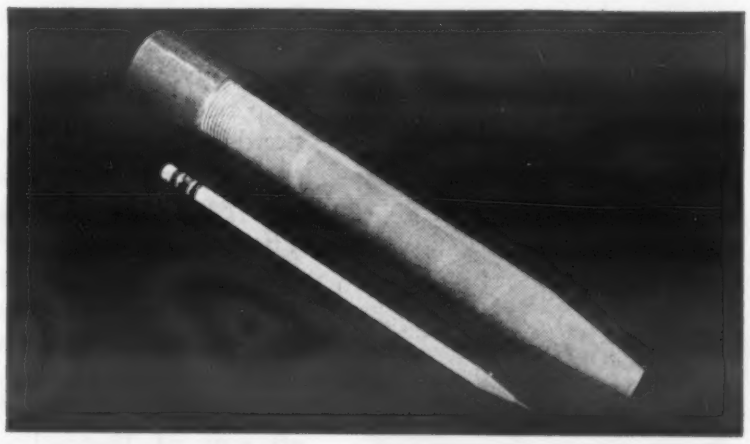


Impingement tests (left) and direct abrasion tests (right) show superiority of silicon-nitride-bonded silicon carbide over other materials.

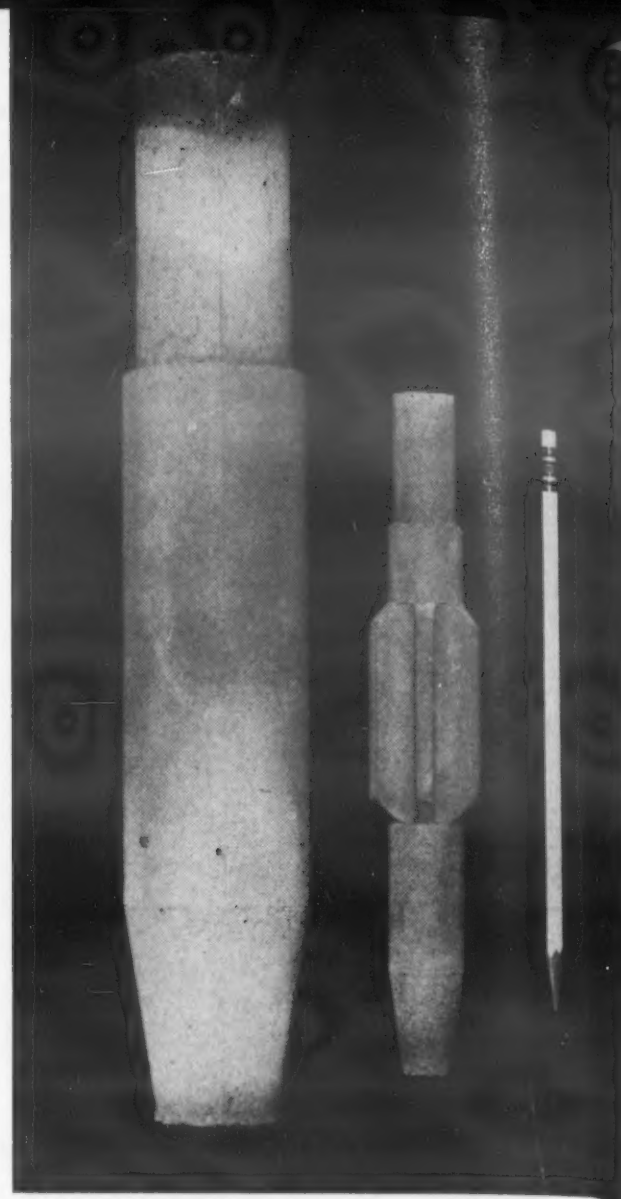
SOME PARTS APPLICATIONS



***REFRAX BOLT** at right resists corrosive conditions at high temperatures. Nut made of the same material turns easily on standard metal bolt and is strong enough to permit tight connections.*



***THREADED REFRACTORY NOZZLE** used in burning acid sludge accommodates standard ¾-in. metal pipe coupling.*



***BURNER TIP** for use in ceramic kiln at 3200 F produced from silicon-nitride-bonded silicon carbide which has low thermal expansion and withstands high temperatures.*

sible to compare the strengths of the new material with stainless steels at 2400 F since the steels cannot be used at temperatures as high as this.

The corrosion resistance of this new bonded silicon carbide is somewhat better than that of the regular bonded silicon carbide product. It is resistant particularly to acids and acid salts. It can be used for the handling of highly corrosive liquids at room and elevated temperatures including such materials as mixed chlorides and the sulfates of iron, zinc and tin containing free acids.

The new product also has excellent resistance to abrasion. Results of impingement and direct abrasion tests on several materials are shown in graphs. The impingement test was performed on a sand-blast machine called the Zeiss hardness tester. In operation this machine directs a blast of air against the surface of the material to be tested while a definite volume of abrasive grain is fed into the air stream. The depth of material abraded from the specimen is a measure of the resistance to impingement. In this test, silicon-nitride-bonded silicon carbide was superior to regular bonded silicon carbide and both materials were far superior to acid-proof brick and paving brick which were included for comparison.

The direct abrasion test was run on a machine developed by the National Bureau of Standards. Essentially the test consists of revolving a notched wheel in contact with the specimen while feeding loose abrasive grain under the wheel. The volume of material removed indicates the relative resistance to abrasion. In this test also, the new material was superior to regular bonded silicon carbide, acid-proof brick and paving brick.

In heat shock resistance, extensive tests have shown that this material is two to three times better than regular silicon carbide.

These properties indicate that Refrax is a valuable addition to the field of materials which can serve under high temperature, corrosive or abrasive conditions. It also has another advantage for it can be produced in shapes which are quite unusual for refractory materials.

Possible Shapes

This refractory can be produced in sections considerably thinner than those obtainable with other refractories. Depending on the over-all dimensions and other characteristics of the part, sections as thin as ¼ in. can be produced.

Parts can be held to tolerances of ± 0.005 in. with surfaces as smooth as those obtained on many metal castings. Complicated shapes can be

made with either internal or external threads. Standard pipe fittings in sizes of 3/8 in. and larger can be produced readily. Standard bolts have been furnished also and tests have shown that these bolts have threads which are two to three times as strong as similar threads on graphite parts.

Applications

An outstanding application of the new material is in part holders for continuous brazing operations. In making squirrel-cage type bearings. for example, use of this production method was forestalled by the inability of alloy holders to carry the weight at brazing temperature. Refractory supports, however, give better than 150 trips without deformation, require no refinishing or grinding to maintain bearing accuracy and the cost is about 1/15 that of alloy. Refrax holders can be made for both simple and intricate pieces. Molds for the refractory parts, which show practically no dimension changes during firing, are produced directly from models.

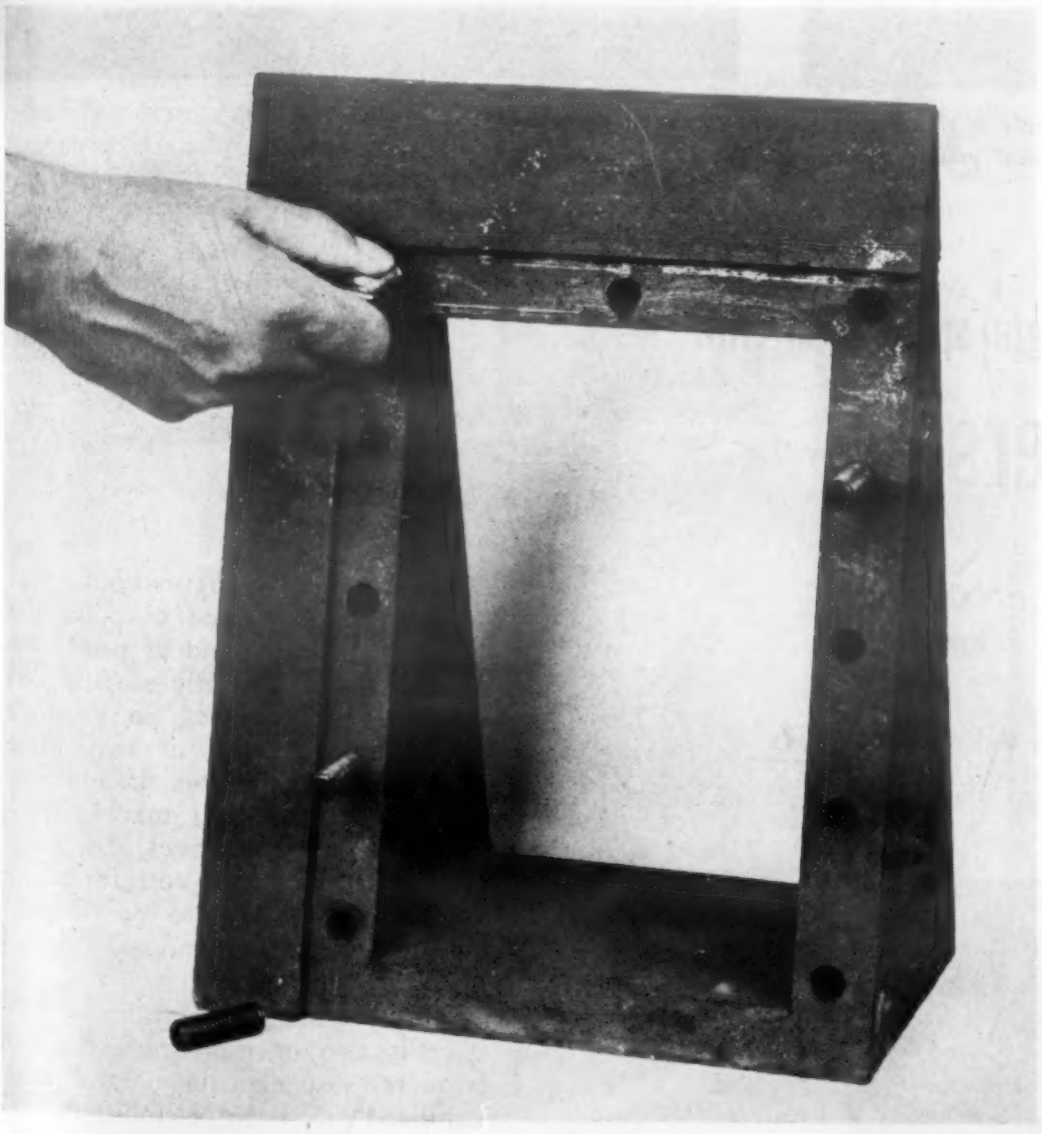
Because of its electrical and heat resisting characteristics, this material makes an excellent microwave absorbant, capable of being used for well-matched wave guides or terminations.

Other applications are just developing for Refrax. Because of its corrosion resistance, it is used for acid spray nozzles. These nozzles are formed with standard pipe threads and are fastened directly to a metal line with a standard metal pipe coupling.

The ability to take a standard thread is utilized also in the production of test racks for flame impingement tests. These racks are made with threaded holes into which bolts are inserted to hold the metal specimens for testing. The rack is able to withstand the testing temperature without difficulty.

The material is not wet nor attacked by molten aluminum and several applications are based on these properties. Aluminizing steel wires, die casting aluminum parts and pumping molten aluminum are but a few of the jobs in which it is used because of these features.

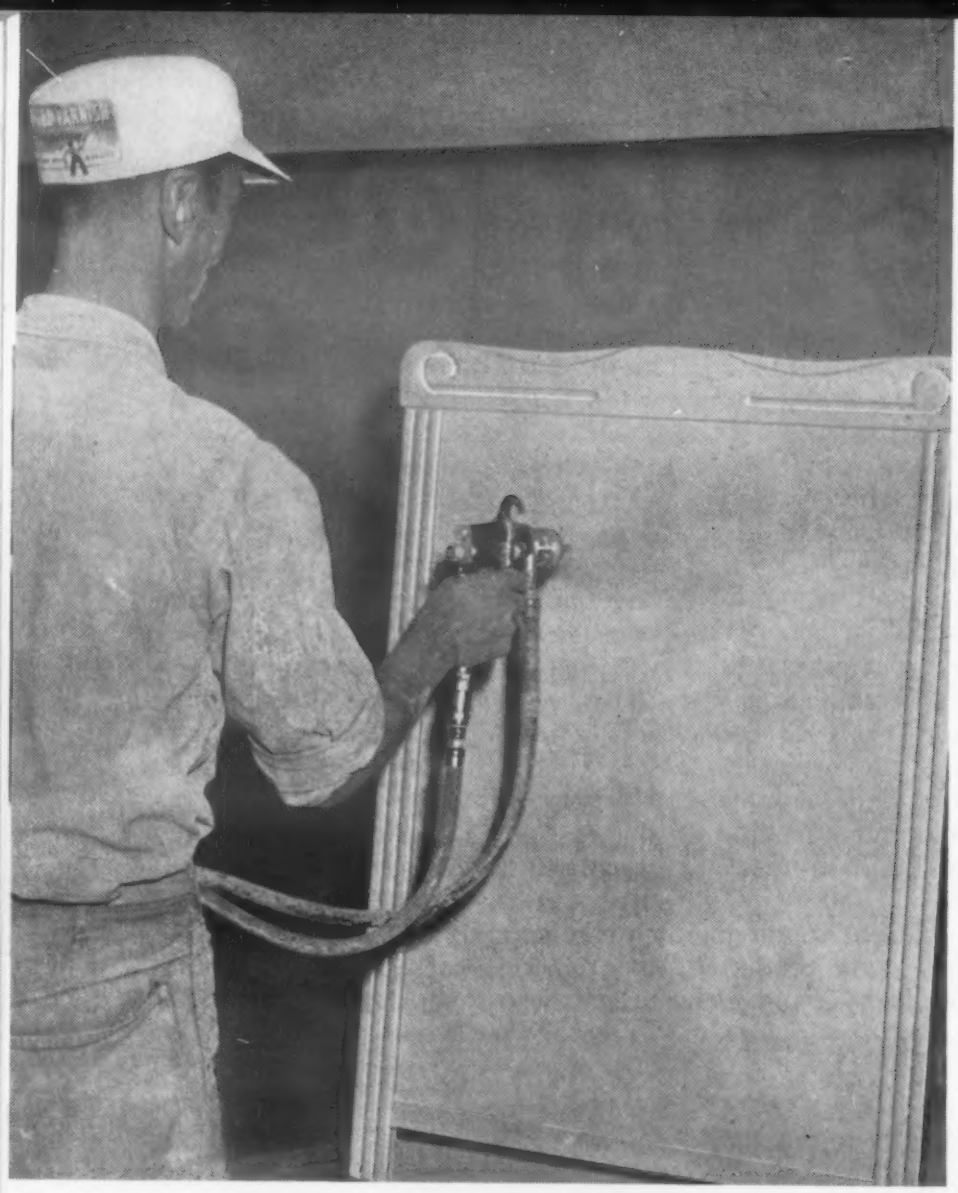
Another use made possible through this non-wetting property, coupled with heat shock resistance, is casting aluminum housings around Refrax shapes. Pump impellers for handling corrosive materials are also under investigation. The ease of producing close-tolerance parts is a major factor in promoting their use for the purpose.



SPECIMEN HOLDER *used in flame testing various materials produced from the new refractory withstands severe heat shock.*

REFRACTORY COUPLING *at left has threads of the same size and pitch as the metal coupling. The refractory coupling resists hot acids and acid salts.*

RABBLE ARM *used in ore roasting operations resists wear, has high hot strength and resists high temperature corrosion.*



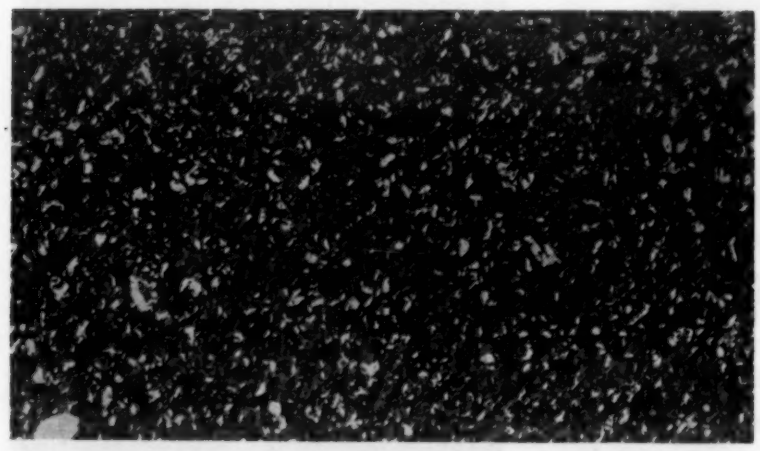
For versatile multicolor lacquers it has been only a short step from caskets and baby furniture to business machines, TV sets and other industrial products. (Maas & Waldstein Co.)

Three different colors in a single application with

Multicolor Lacquers

—a new product finish that is attractive, durable and can be sprayed on 5 mils thick.

by JOHN B. CAMPBELL, Associate Editor, Materials & Methods



A typical three-color pattern—life-size. (Maas & Waldstein Co.)

● NOBODY has yet figured out a way to spray on a striped or polka dot paint, but a new kind of paint now on the market is only slightly less fantastic. It provides, in a single application, a finish of two, three or more different colors. In addition, this multicolor finish may be produced in various textures, it is thick and durable, and its cost for many applications appears to be comparable to that of conventional organic finishes.

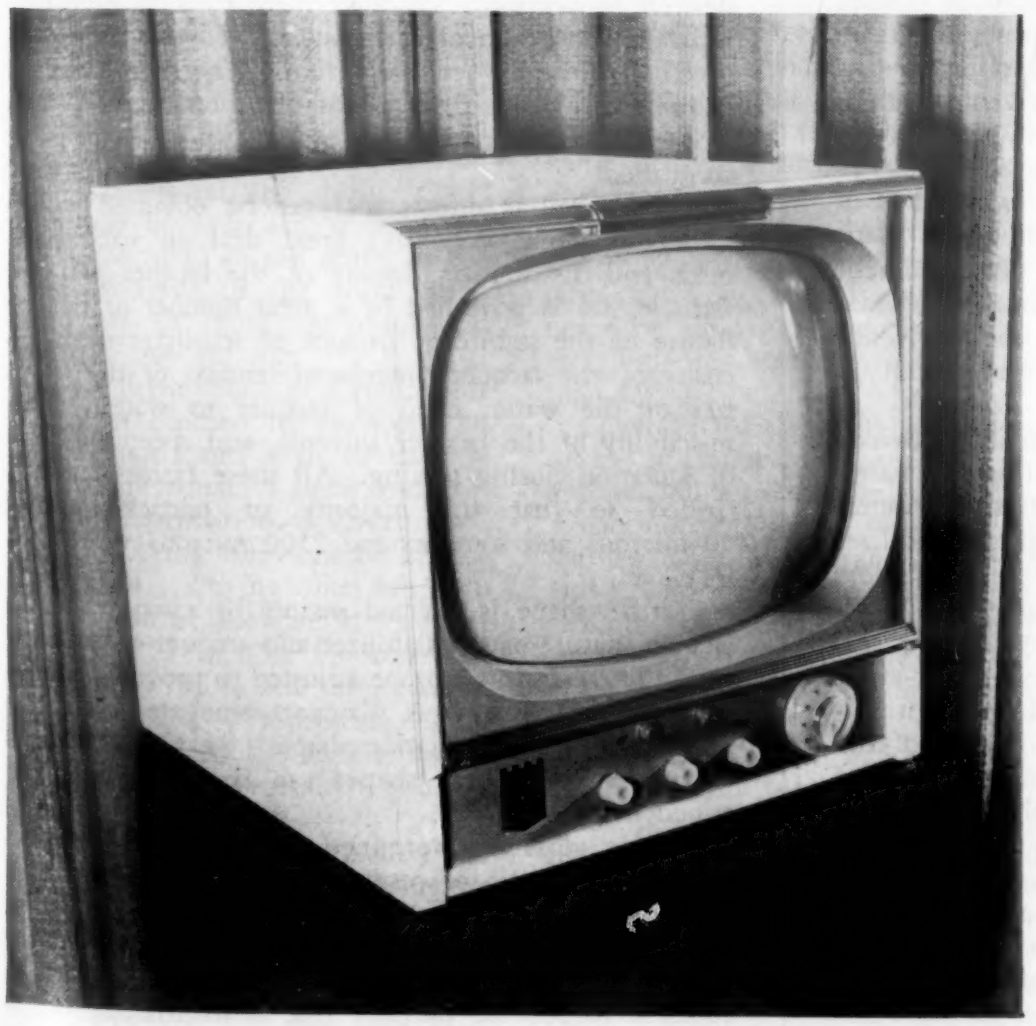
Simply described, a multicolor lacquer is two or more nitrocellulose lacquers suspended in water and stabilized to prevent blending of the different-colored particles. These particles remain separate during application and drying, and they are large enough to form a distinct color pattern. Many different particle shapes are possible.

Actually, multicolor lacquers are

several years old. It has been only fairly recently, however, that they have grown from a wall finish for architectural applications, where they started, to an accepted finish for industrial products.

The development of commercial multicolor paints is based on U. S. patent No. 2,591,904, issued in 1952 to John C. Zola of Arcadia, Calif. Licenses under this patent are controlled by Coloramic Coatings, Inc., of Los Angeles and the first producer of multicolor lacquers was Paramount Paint & Lacquer Co. of that city. It was followed by Maas & Waldstein Co. of Newark, N. J., which contributed greatly to the commercial development of multicolor lacquers and is reported to be the largest supplier at the present time. Many additional suppliers have entered the field and multicolor lacquers are now being produced under a great variety of trade-names.

Most suppliers offer both standard single colors and selected mixtures of colors. They also provide additional single colors or mixtures to order. The single colors may be mixed as desired by the customer. One company lists 20 standard single colors; another has 38. Although there are an infinite number of possible color combinations, some favorites have developed. One company reports a preference for a white background with gray and yellow specks. Another lists gray-white, brown-red, white-pink, white-yellow, green-yellow and ivory-brown as most popular. Simulated textures such as mahogany and light oak also appear to be in demand, especially for furniture.



Multicolor lacquer on wood or masonite is an attractive, durable and economical combination for TV cabinets.

Advantages

Following are the major advantages of this new type of paint:

1. A multicolor finish can be obtained in one application. With conventional paints as many applications as colors are ordinarily required and each color is only superficial. Attempts to spray two or more paints simultaneously have not been highly successful.

The multicolor feature itself has several advantages. Surface wear and minor scratches are hard to detect because of the multicolor pattern and the fact that it is continuous throughout the film thickness. Thus, filling of minor cracks, checks and damaged areas, and "feathering" of tapes used to cover joints can often be eliminated. Also, color matching is simplified because slight differences in shade are not so apparent as in solid colors. Thus severely damaged areas can be effectively retouched.

2. A special texture, such as simulated leather or stippled, can be obtained in one application without additional procedures or equipment. The texture may be in one or more colors. Conventionally, stippled finishes are produced by mechanical treatment of the surface immediately after coating.

3. A single coating as thick as 5 mils can be applied. Ordinary lacquers are limited to a single-coat thickness of one or, at the most, two mils; thicker coatings tend to sag, run, wrinkle, alligator or even blister. When properly formulated and applied heavy, a multicolor finish is tough and has extremely high abrasion resistance. It resists continued scrubbing with mild alkalies or normal household cleaners.

4. The relatively large particle size of the suspension means that a porous surface can be coated without previous sizing.

5. Porosity of the finish can be controlled within a wide range. It may be microscopic, or it may have scatter sufficient to allow an undercoat to show through.

6. A minimum of overspray is produced in spraying these finishes, so that costly masking operations ordinarily required can sometimes be eliminated.

Probably the most important disadvantage of a multicolor lacquer is the inherent porosity that limits its usefulness in outdoor applications. A certain amount of porosity is not surprising in a finish which is applied in the form of relatively large, discrete particles. However, although the more conservative suppliers do not recommend multicolor lacquers for outdoor applications, especially on metals, these finishes, applied over properly formulated primers, are being used for more than one outdoor application with apparent success. Furthermore, there are indications that porosity can be reduced somewhat by certain changes in formulation now being investigated.

Uses

The peculiar characteristics of multicolor lacquers make them especially suitable for these types of applications:

1. A finish for rough surfaces. Applied heavy, the lacquer produces a finish that appears smoother than

the original surface.

2. A finish for adjacent surfaces of different absorbent properties. Applied heavy, the lacquer tends to obscure the difference between the two original surfaces. A good example is a rough wooden article where the end of a board may be adjacent to the smooth planed surface of another board. Another is a cabinet made of both wood and masonite.

3. A finish for porous surfaces. Examples of surfaces that can be finished satisfactorily with one heavy coat are composition boards, wallboards, soft unfinished wood, felt, fabrics and paper.

4. An attractive finish for a low-

How a Multicolor Finish Gets That Way

The key to a multicolor finish lies in the formation of individual droplets of coating material which are large enough to be visible, and which retain their separate identities in the dry film. Since the individual droplets do not mix they may be of different colors. When dry, the particles form a pattern in which the colors occur in a statistical distribution according to the color proportions selected.

As applied, a multicolor finish consists of a coating material dispersed or suspended in a liquid with which it is relatively immiscible. The preferred dispersing medium is water containing a stabilizing agent. Unlike lacquer-in-water emulsions, these suspensions are not appreciably affected by small amounts of electrolytes dissolved in the dispersing medium; hence ordinary tap water can be used instead of distilled water. In addition to a stabilizer, the water may also contain other agents to adjust pH or surface tension, both of which affect particle size.

The stabilizing agent, which may be either organic or inorganic, is generally a colloidal material more or less soluble in the water. The stabilizer apparently forms a protective layer around individual particles of coating material, causing them to repel each other and remain discrete. For nitrocellulose lacquers and other coating materials containing the same kind of solvents, such as mixtures of the organic alcohols, ethers (or esters) and hydrocarbons, the best known stabilizer appears to be methyl cellulose (viscosity: 15 cps) in amounts of 0.3 to 2% by weight of the dispersing medium. Many other agents are suitable as stabilizers. For synthetic enamels and oil-base paints, which ordinarily contain aromatic and aliphatic hydrocarbons as their solvents, medium-viscosity polyvinyl alcohol in the amount of 0.5 to 5% has been recommended.

Theoretically, any coating material is suitable provided it does not contain too high a proportion of water-soluble solids nor too high a proportion of water-miscible solvents, and provided an appropriate stabilizer is used. Possible coating materials include nitrocellulose lacquers, various synthetic and natural resin enamels, oil-base paints, solutions of polymerized synthetic resins (such as vinyls, acrylics, styrenes and ureas), water-in-oil type emulsions of these materials, etc. However, multicolor finishes now on the market are primarily of the cellulose lacquer type. Development of other types has been obstructed by serious stability problems.

The major difference between the lacquer in a multicolor finish and a conventional lacquer lies in its much higher viscosity. Since the aqueous dispersing medium acts as a thinner, the lacquer solvents need not be relied upon for thinning, and a high solids content is possible. High viscosity promotes a thicker film and less penetration on a porous base. The particles of a high-viscosity lacquer also tend to retain their shape after being applied to a surface and to harden without substantial change in shape. This property makes possible definite controlled patterns and textures.

A single-color dispersion or suspension is formed by pouring the lacquer into the water and agitating the mixture to break up the lacquer into the desired particle size. The optimum ratio of lacquer to water depends on the lacquer and the stabilizer but 4.0 is about the maximum desirable; in greater proportions, the lacquer tends to coalesce in time, resulting in poor shelf life. The ordinary range is 1.0 to 3.0 for thick, dense films and correspondingly less where an open or porous finish is desired. The suspension can also be prepared with a minimum of water and then adjusted to proper consistency before application simply by adding tap water and stirring. Excessive water produces an inferior film, apparently because the particles have time to coalesce before all the water evaporates.

A multicolor finish is a multiple suspension that can be made in either of two ways. One method is to prepare a single-color suspension with excess water and then mix in the additional lacquers one at a time in the desired proportions. Another method is to prepare a separate suspension of each lacquer and then mix them together in the desired proportions. The second method is preferable since the amount of agitation given each lacquer, and hence its particle size, can be more easily controlled.

The decorative effects that can be obtained with a multicolor finish depend a great deal on size, shape, gloss and distribution density of the lacquer particles. Particle size is governed by a great number of factors: nature of the stabilizer, amount of stabilizer used, viscosity of the lacquer, interfacial tension of the water, pH of the water, ratio of lacquer to water, water-miscibility of the lacquer solvents, and speed and time of agitation during mixing. All these factors are controlled so that the majority of particles exceed 50 microns and some exceed 2500 microns (about 0.1 in.).

Particle shape is affected mainly by viscosity of the lacquer, nature of the stabilizer and amount of stabilizer used. These factors may be adjusted to provide particles in shapes such as spheres, filaments, elongated ovals, tear drops and other irregular shapes. If the lacquer is viscous enough, these shapes can be substantially retained in the dry film.

Particle gloss is determined, as in conventional lacquers, by the ratio of resin and plasticizer to pigment. Particle distribution density or porosity of the finish depends on the ratio of lacquer to water. The lower the ratio the more porous the finish. The ratio can be adjusted to provide porosity that is microscopic or, at the other end of the scale, porosity that is visible enough to allow an undercoat to show through.

cost surface. Since a heavy multicolor finish tends to hide the character of the original surface, it is possible to use a cheaper structural material for a product and improve its saleability by means of a multicolor finish. A current example is the use of masonite or inexpensive wood with a multicolor lacquer for TV cabinets.

5. A finish of unique appearance for sales appeal. The wide variety of colors, textures, porosities, degrees of gloss, and particle shapes and sizes make possible limitless decorative effects beyond the more functional advantages listed here.

A partial list of current product applications includes business machines, laboratory equipment, caskets, baby furniture, typewriter cases, file boxes, radio and TV cabinets, mirror frames, wood novelties, store displays and racks, machinery and switchgear housings.

Application

Ordinarily, a primer should be used under a multicolor finish. Although the finish can be applied directly to porous surfaces, use of a primer-sealer improves uniformity of pattern and texture. The water base makes direct application to metal or ceramic surfaces inadvisable and normal priming procedures should be followed. However, many other common finishing steps can often be eliminated because of the exceptional hiding power of the finish. Great care must be exercised in applying the lacquer over an old finish, as the strong solvents in the formulation are likely to cause softening and lifting of the old film.

Usual drying time of a multicolor lacquer is claimed to be about 30 min to touch and 4 hr to hard at room temperature. A more conservative recommendation is "overnight" drying. Drying time can be cut by force drying. Drying times of 30 to 60 min, can be obtained at temperatures of 130 to 150 F. Somewhat longer times, up to 2 hr, are required at 110 to 120 F. Temperature should in no case exceed 180 F. The longer drying times generally produce smoother finishes.

Currently, multicolor lacquers are being applied only by spraying. Standard spray equipment may be used. The air caps and fluid tips on the spray gun must have relatively large apertures. Air and fluid pressures may range from 20 to 60 psi; the higher pressures tend to give smaller color patterns, but this effect can be minimized by pulling the gun trigger fully open when spraying and maintaining a good flow of material. The finish should be sprayed at a temperature between 65 and 80 F. The strainer should be removed from the line. Siphon type guns have not always proved satisfactory.

A multicolor lacquer must not be agitated with high-speed mixers. Some suppliers recommend gentle stirring with wooden paddles, but others suggest the lacquer not be stirred at all but merely shaken by hand or by a mechanical shaker. For prolonged storage, temperature should be maintained between 60 and 80 F. Because of its water content, a multicolor lacquer should never be allowed to remain in contact with an iron container longer than 12 hr.

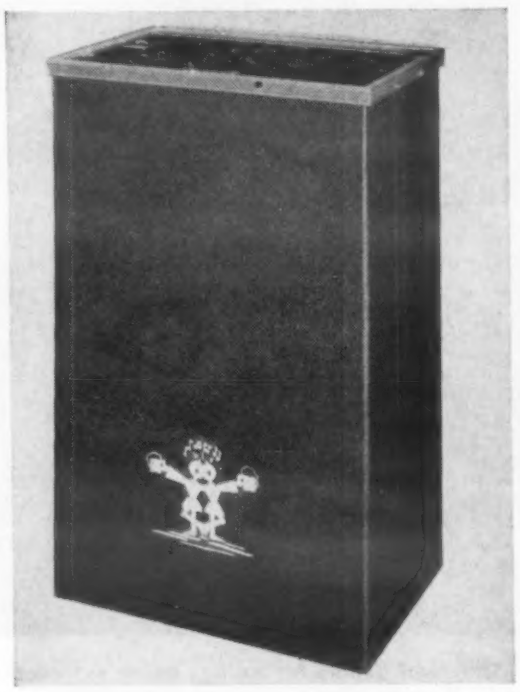
Coverage varies widely depending on the thickness and porosity of the applied finish. On a sealed surface, a continuous 5-mil coating can be applied with a coverage of about 100-125 sq ft/gal. For open decorative effects, coverage may be as high as 400 sq ft/gal. Slightly less coverage would be expected on a porous surface.

Cost of standard multicolor lacquers generally varies from $3.50 to $5.00 per gal, depending on quantities and types of containers desired. At $4.00/gal the materials cost of a continuous thick multicolor finish would be about $0.04 per sq ft. Considering the cost of second and third coats generally needed with conventional lacquers, the cost of a multicolor finish appears to be comparable with that of more conventional finishes.

Basic Formula for a General-Purpose Multicolor Cellulose Lacquer*

Coating Material, %		mixed about 2:1 with	Dispersing Medium, %	
RS Nitrocellulose (5–6 sec)	7.0	Solids	Methyl cellulose (4000 cps.)	0.5
Cellolyn 102	10.0		Water	99.5
Dibutyl phthalate	3.0			
Titanium dioxide (or other pigment)	4.0			
Talc	6.0			
N-Butyl alcohol	3.5	Volatiles		
Methyl amyl acetate	40.0			
Xylene	26.5			

* *This prototype formula is given for illustrative purposes only and is not necessarily representative of multicolor lacquers now on the market. All proportions by weight.*



A darker multicolor pattern is used on this home bar unit. (United Lacquer Mfg. Co.)

Acknowledgment

This article is based on information contained in U. S. Patent No. 2,591,904, plus information furnished by the Cellulose Products Dept. of Hercules Powder Co. and by the following suppliers of multicolor finishes:

Atlas Powder Co., Industrial Finishes Dept., Stamford, Conn., and N. Chicago, Ill. (Zatex)
Baltimore Paint & Color Works, Baltimore, Md. (Gleem Colorscope, Vari-Colored Enamel)
Lasting Products Co., Baltimore, Md. (Polytone)
Maas & Waldstein Co., Newark, N. J., Chicago, Ill., and Los Angeles, Calif. (Plextone)
Reliance Varnish Co., Inc., Louisville, Ky. (Speckle-Tone)
United Lacquer Mfg. Corp., Linden, N. J. (Multakolor)
Vari-Krom, Inc., Hoboken, N. J. (Vari-Krom)

Structural beams for trailers being extruded out of the new high-strength 6066 aluminum alloy.

Two New Alumium Extrusion Alloys

Developed by Harvey Aluminum, each is expected to foster many new applications for light extrusions.

—New Materials Preview

1. A General Purpose Alloy

Of wide industrial importance is the new aluminum alloy, 6066 (66S). It is a general purpose aluminum alloy, containing magnesium and silicon, which bridges the gap between the lower-strength 6061 (61S) type alloy and the higher-strength hard alloy 2024 (24S). Development of 6066 is of prime consequence to the wide segment of industry that needs a strong, lightweight material at the cost level of lower-strength metal alloys.

Alloy 6066-T6 has a typical ultimate strength of 57,000 psi. Its most

desirable features are high strength, weldability and corrosion resistance similar to 6061, fabricating characteristics practically identical with that of lower-strength 6061, and low cost.

Development of Harvey's 6066 is of paramount importance to designers faced with the problem of saving weight in materials and maintaining good strength characteristics or even improved strengths. Harvey design engineers estimate that in certain aluminum components of a typical truck and trailer, material costs can be reduced by 22.4%. The results are a lower cost-per-mile transportation operation and a bigger payload capacity.

Harvey designers also have found that by using high yield strength 6066 in a typical cross section of a building structure, a 21% saving in material costs was made with no sacrifice in strength. The use of 6066 also reduced original costs and weight handling.

Table 1 shows the mechanical properties of 6066, and Table 2 compares strength of 6066 with some other aluminum alloys and steel. The alloy can be heat treated as well as artificially aged to obtain higher strengths.

Table 1—Mechanical Properties of 6066

	Thick, in.	Ult Str, psi	Yld Str, psi	Elong, %
Guaranteed				
6066-T6	up to ¼	50,000	45,000	8
(66S-T6)	¼ and over	55,000	48,000	9
Typical				
6066-T6	up to ¼	57,000	52,000	11
(66S-T6)	¼ and over	62,000	55,000	12

Table 2—Design Strength Comparisons of 6066
(Guaranteed Yield Strength)

Material	Thick, in.	Yld Str, psi
2024-T4 (24S-T4)	0.050–0.249	42,000
	0.250–0.749	44,000
	0.750–1.499	46,000
	1.500 over	52,000
6066-T6 (66S-T6)	up to ¼	45,000
	¼ and over	48,000
6061-T6 (61S-T6)	All	35,000
Structural Steel (ASTM A7-527)	All	33,000

NOTE: Yield values only are shown because these are most important in designing for structural applications.

2. A High Strength Alloy

The second new alloy recently developed in Harvey's metallurgical laboratories was the high-strength aluminum alloy HZM 100. This alloy was developed to obtain the optimum mechanical property pattern in such wrought products as extrusions and forgings, and still maintain a desirable balance with other important characteristics. The high-strength requirements of the aircraft industry also came in for special consideration in the development of HZM 100.

HZM 100 has the highest strength (typical ultimate strength of approximately 100,000 psi) of any commercial aluminum alloy yet developed. In addition to these strength qualities, this new alloy retains the ductility and many of the other desirable characteristics of 7075.

Among the characteristics of this alloy are a guaranteed tensile strength of 89,000 psi and guaranteed yield strength of 82,000 psi in thicknesses up to ¼ in. Tests indicate that the compressive yield strength ranges from 100 to 110% of the tensile yield strength.

Producibility of HZM 100 is identical with 7075 alloy on all existing extrusion dies, and tests to date show that mechanical properties for forging the alloy are an improvement over 7075 alloy forgings. Table 3 shows the mechanical properties of HZM 100, and Table 4 lists the strength comparisons of HZM 100.

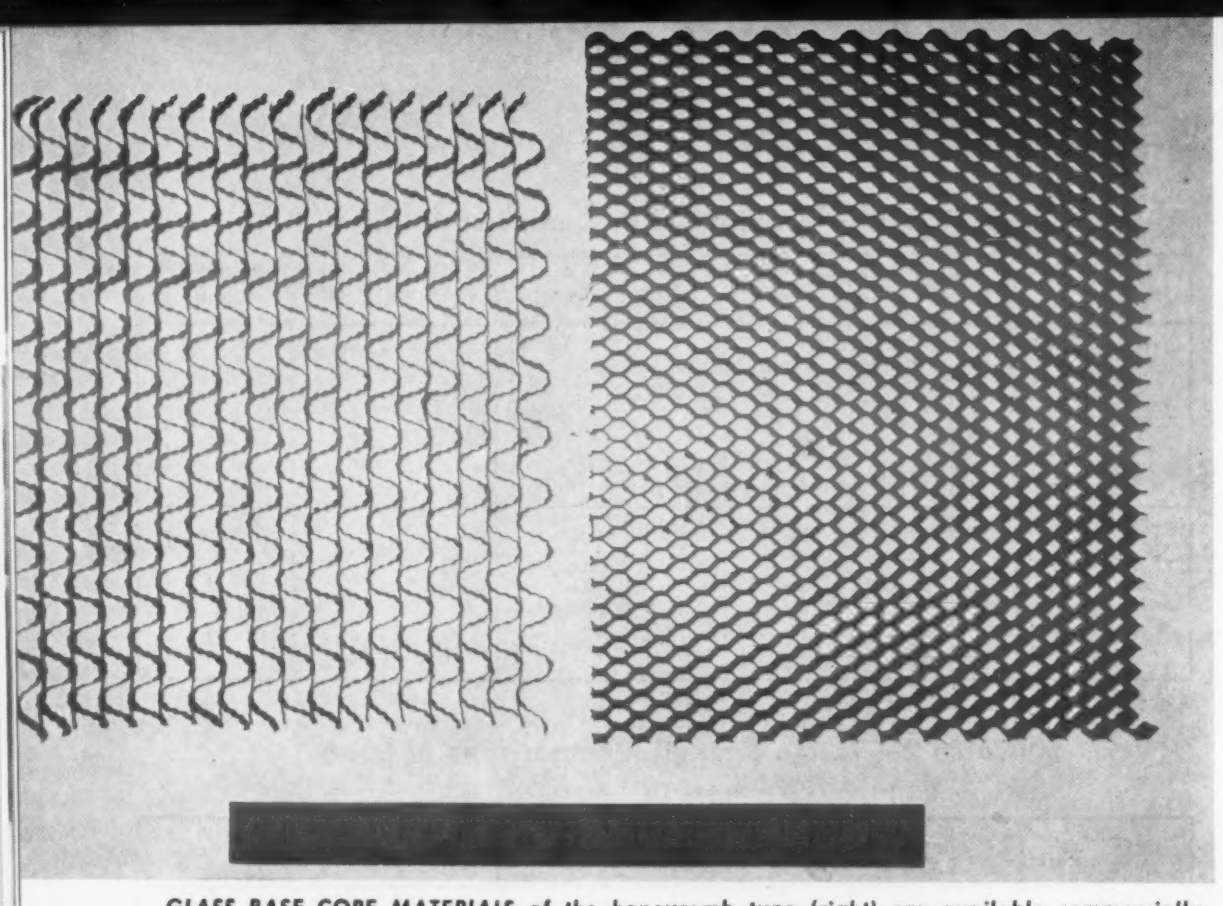
Table 3—Mechanical Properties of HZM100

	Thick, in.	Ult Str, psi	Yld Str, psi	Elong, %
Guaranteed HZM 100-T6	up to 0.249	89,000	82,000	7
	0.250–0.749	92,000	84,000	7
	0.750–2.999	90,000	84,000	7
Typical HZM 100-T6	up to 0.249	96,000	88,000	10
	0.250–0.749	100,000	92,000	9
	0.750–2.999	98,000	92,000	9

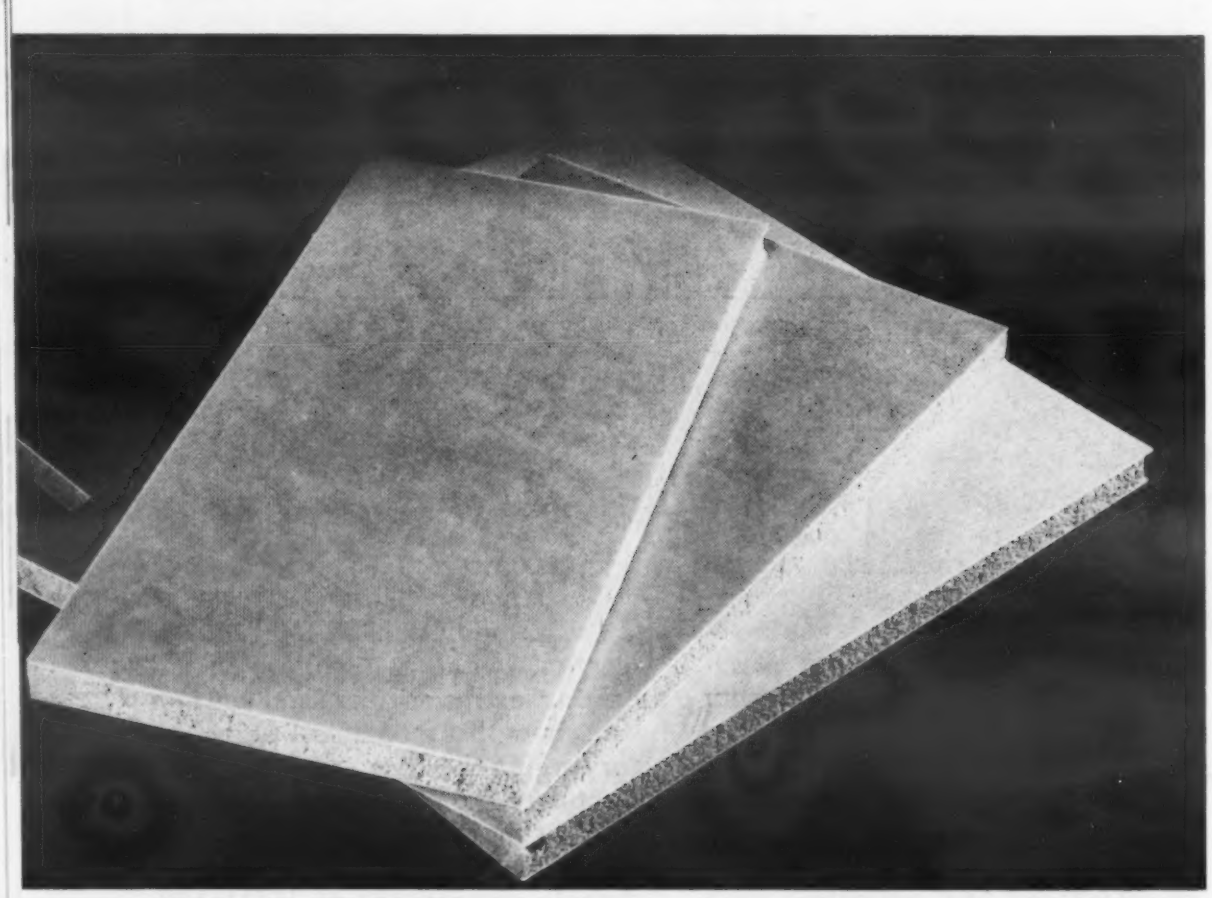
Table 4—Design Strength Comparisons of HZM100
(Guaranteed Yield Strength)

	Thick, in.	Yld Str, psi
7070-T6 (75S-T6)	0.294 and less	70,000
	0.250–2.999	72,000
	3.000–4.499	70,000
HZM 100-T6	up to 0.249	82,000
	0.250–0.749	84,000
	0.750–2.999	84,000

NOTE: Yield values only are shown because these are most important in designing for structural applications.



GLASS BASE CORE MATERIALS *of the honeycomb type (right) are available commercially, while the multiwave type (left) will soon be marketed.*



EXPANDED SILICONE-BASE CORE *is used here with glass reinforced silicone-base plastic laminated facings. (Dow Corning Corp.)*

Aircraft industry has developed—

Sandwich Materials For High Temperature Uses

A number of different constructions have already proved serviceable in the 300 to 500 F temperature range . . . Besides aircraft, they will be useful in other structural and electrical applications.

by **IRVING KATZ**, Research Engineer, North American Aviation, Inc.

● THE SUCCESS experienced with sandwich type structures in recent years has extended development work into many new fields of application. One of the newer extensions is the evaluation of sandwich construction, limited to glass reinforced plastic materials, for use in structural and electrical applications subjected to elevated temperatures in the range of 300 to 500 F. This has been brought about mainly by the aircraft industry whose needs call for lightweight, strong structures capable of withstanding elevated temperatures generated by high speed flight.

Materials

At elevated temperatures, the standard aircraft structural metals, e.g., aluminum and its alloys, do not have the intrinsic strength necessary for resisting the stresses involved in high speed flight. The more temperature stable structural metals, e.g., steel and its alloys, are too heavy, cutting down the potential payloads.

Research engineers have developed several new lightweight materials that do not suffer the detrimental loss in strength at elevated temperatures. The elevated temperature resistant, glass reinforced plastic laminate is one of these new materials. At present, only a limited number of resins can be employed in preparing these temperature resistant plastics. Triallyl cyanurate-modified polyesters, silicones, and certain phenolics are examples (see Table 1).

The methods by which these resinous materials polymerize into cured polymers are strikingly different, accounting in part, for the choice of the resin and the subsequent fabrication operation. For example, addition type polymers, of which triallyl cyanurate-modified polyesters are typical, require the following considerations:

1. The catalyzed resin impregnated glass fabric has a relatively

short shelf life. The fabricator must either provide impregnation equipment to prepare this fabric just prior to use or provide ample space and equipment for cold storage, in which case he may buy it ready for use from commercial impregnators.

2. The catalyzed resin in the impregnated glass fabric polymerizes in a single rapid reaction sequence liberating no by-products. The fabricator can cure this material rapidly and in quite thick sections, provided he has suitable heating media.

3. The starting costs for impregnation and allied equipment are high, while the subsequent fabrications costs are relatively low.

On the other hand, the condensation type polymers, of which phenolics and certain silicones are examples, require these considerations:

1. The catalyzed resin impregnated glass fabric has a relatively long shelf life. The fabricator can buy the materials from commercial impregnators, eliminating the need for impregnating equipment and cold storage space.

2. The catalyzed resin in the impregnated glass fabric polymerizes by a slow stepwise reaction sequence, liberating by-products. The fabricator must use relatively long cure cycles and be limited to relatively thin sections during any one cure operation in order to avoid blistering due to released volatile by-products. However, thick sections can be fabricated by a stepwise lay-up.

3. The starting costs are low (no impregnation or refrigerating equipment), but the subsequent fabrication costs are high.

Facings—The facings for sandwich structures are the elevated temperature resistant glass reinforced plastic laminates. Any of the three types of resinous materials listed in Table 1 can be used for fabricating the sandwich facings.

Each of these resinous materials (in the form of a plastic laminate) has certain outstanding properties, such as extreme temperature resistance, high strength, low costs, etc. Since no single resin-glass fabric combination is outstanding in all of these features, a knowledge of the general properties offered by each type helps direct development work toward that combination which appears attractive for the particular application (see Table 2).

Cores—At present, the core materials available for heat resistant sandwich construction are limited to

***EXPANDED PHENOLIC-BASE RESINS** used for cores can be foamed at room temperature.*

phenolic resin impregnated glass base honeycomb, and silicone and phenolic expanded plastics (see Table 3). The substitution of silicones and triallyl cyanurate-modified polyesters for the phenolic resin in the honeycomb is still in the early experimental stage. However, a number of phenolic resin impregnated honeycomb cores are available commercially. A new type, the phenolic resin impregnated glass base multiwave core will soon be available from Narmco Metlbond Co.

For primary structural applications, expanded plastics are generally usable only in conjunction with glass honeycomb core to provide addi-

Table 1—Commercial Resins Suitable for Elevated-Temperature-Resistant Plastic Laminates

Type	Designation	Manufacturer
T. A. C. Modified-Polyesters	PDL 7-669	American Cyanamid Co.
	Vibrin 1047	Naugatuck Chemical Div., U. S. Rubber Co.
Silicones	DC 2104	Dow Corning Corp.
	DC 2106	Dow Corning Corp.
	DC 2103	Dow Corning Corp.
	DC 2105	Dow Corning Corp.
Phenolics	BV 11946	Bakelite Co.
	BV 17085	Bakelite Co.
	Conolon 506	Narmco Resins & Coatings Co.
	CTL-91-LD	Cincinnati Testing Laboratories
	G. E. 12304	General Electric Co.
	G. E. S1047	General Electric Co.
	Plyophen 5023	Reichhold Chemicals, Inc.

Table 2—Characteristics of Glass-Reinforced Plastic Laminates

Property	Triallyl Cyanurate Modified Polyester	Silicone	Phenolic
Temperature Resistance	lowest	highest	intermediate
Mechanical Properties	intermediate	lowest	highest
Processing Difficulties	lowest	highest	intermediate
Cost			
Material (ready for use)	highest	intermediate	lowest
Fabrication	lowest	highest	intermediate
Pot Life	lowest	highest	intermediate
Lay-Up	wet	usually dry	usually dry

Table 3—Commercially Available Core Materials

Type	Designation	Manufacturers
Phenolic Impregnated Glass Honeycomb	(a) CTL 3/16–112–6.5 CTL 3/16–112–9.0 CTL 1/4–21–6.0 CTL 1/4–21–8.0 (a) BVQ 3/16–112–6.5 BVQ 3/16–112–9.0 BVQ 1/4–21–6.0 BVQ 1/4–21–8.0	California Reinforced Plastics Co.
Silicone Foam	XR 543 XR 544	Dow Corning Corp. Dow Corning Corp.
Phenolic Foam	NA2–4192	North American Aviation, Inc.

NOTES: (a) Fractional symbol 3/16 or 1/4 = cell size in in.; 112 or 21 refers to type of glass fabric; 6.5, 9.0, 6.0 and 8.0 refers to density in lb/cu ft.

Table 4—Elevated-Temperature-Resistant Phenolic-Base Adhesives

Designation	Manufacturers
422	Shell Chemical Corp.
CHT	North American Aviation, Inc.
302	Narmco Resins & Coatings, Inc.

tional skin stabilization. Alone they do not possess sufficient strength at elevated temperatures to make them attractive for this kind of application. For secondary and non-structural applications they can be used singly.

The silicone base expanded plastics can be foamed in place only at elevated temperatures, while the phenolic base expanded plastics can be foamed at room temperature. However, to obtain the maximum strength properties from both types, heat treating is necessary.

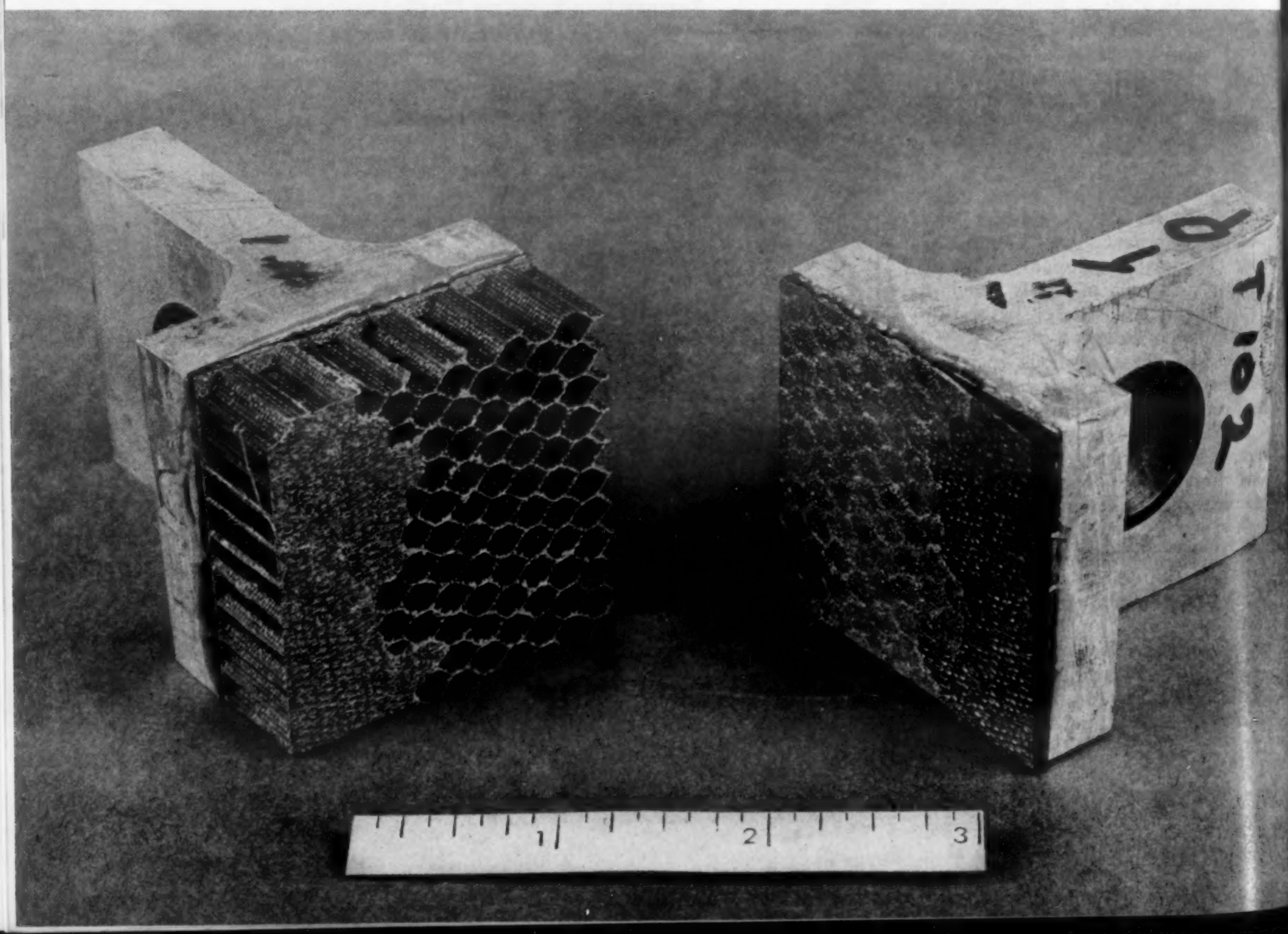
Adhesives—the adhesives used in fabricating heat resistant glass reinforced plastic sandwich structures can also be prepared from the identical resins that make up the sandwich facings. However, certain modifications especially for secondary bonding may be required, depending on the extent of brittleness, strength and coefficients of expansion. The adhesive may be used either non-supported or in the form of a supported tape.

A number of phenolic resins have been modified (see Table 4) to provide adhesives ready for use in secondary bonding operations. Since these adhesives are designed primarily for phenolic-base sandwiches, the fabricator is obliged at present to develop his own adhesives for the other resin-base sandwich structures fabricated by secondary bonding operations. In any event, the vendor of elevated temperature resistant resins will supply information covering his respective products.

Fabrication Techniques

There are four general methods for fabricating sandwich structures. These include:

***PHENOLIC-BASE SANDWICH** specimen after flatwise tensile test at 500 F (1/2-hr conditioning at test temperature).*



1. One Stage Primary Lay-Up. Both skins are molded and bonded to the honeycomb core in one integral operation; the laminating resin serves as the adhesive.
2. Two Stage Primary Lay-Up. Skins are molded and bonded, one at a time, to the honeycomb core in one integral operation; the laminating resin serves as the adhesive.
3. One Stage Secondary Lay-Up. Both pre-molded skins are bonded to the honeycomb core simultaneously; the laminating resin or a modified resin can serve as the adhesive.
4. Two Stage Secondary Lay-Up. Pre-molded skins are bonded one at a time to the honeycomb core; the laminating resin or a modified resin can serve as the adhesive.

The relative advantages of the primary and secondary lay-ups stem from certain differences inherent in each of the processes. For example, in primary lay-ups the operation is cheaper, since the molding step is accomplished at the same time the bonding occurs. However, the laminate skin does not have the benefit of a uniform molding pressure throughout the cycle, since it is in direct contact with the honeycomb core. Consolidation of this type of lay-up depends mainly upon resin flow. In lay-up operations, the fitting of skins to core is a relatively minor problem, since only the core material needs to be contoured.

On the other hand, the secondary type lay-up is more expensive because two distinct processing steps are required, namely, pre-molding of skins and then bonding. Here, however, the skins have had the advantage of a uniform molding pressure, and, therefore, the mechanical properties will tend to be better. Bonding of skins to core depends on the ability of the adhesive to provide strong primary (or at least strong secondary) chemical forces between the molded skins and the C-stage honeycomb core. In lay-up operations, fits are considerably more difficult, as skins and cores must be relatively closely contoured. Slight variations are permissible if suitable tooling is employed during the bonding operation.

The primary and secondary lay-ups can be performed in either one or two stages, depending upon certain conditions that may arise due to the material choice or design considerations. The one stage operation, which is the cheaper, may lead to difficulties such as placing of inserts, addition of a foaming resin, provision for volatile release, etc. These may in part be eliminated by using a two stage operation. The one stage lay-up is preferred wherever possible.

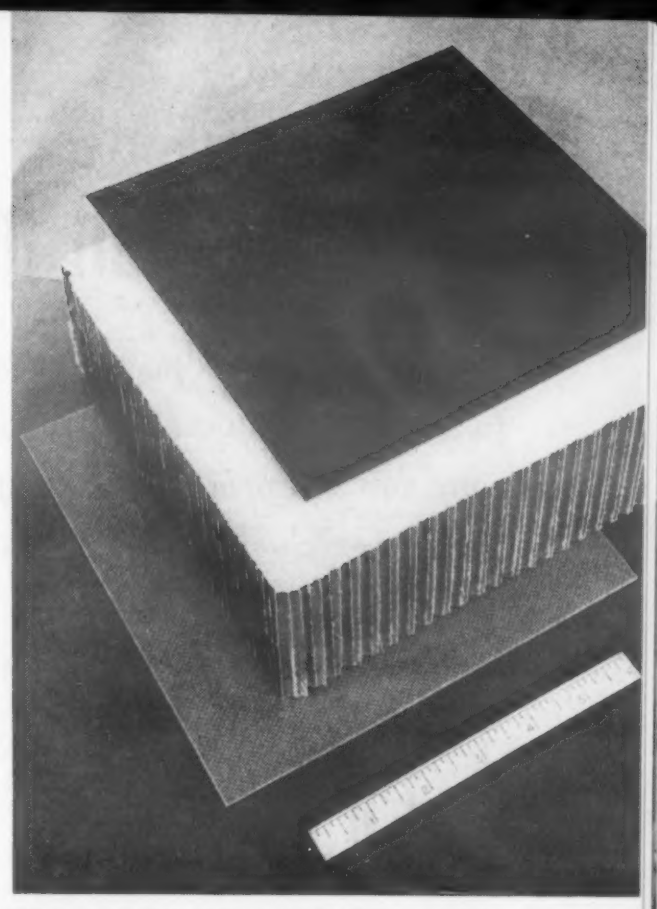
Design and Applications

Most structures, especially in aircraft, are large and contoured. Compression matched molding of laminates and sandwiches is an expensive operation, considering that the mold (with cut-off rings) costs approximately $1000 per lb of laminate. Prototype parts cannot reasonably be made by this method since changes, which certainly there will be, might prevent successful completion of the project.

Low pressure molding on low cost dies permits the fabrication of such parts and allows changes due to modified designs or developmental studies without serious financial losses. However, low pressure molding of resin-impregnated glass fabric produces laminates prone to mechanical strength variations whenever tight controls are non-existent both for the raw materials and for the fabrication operations.

Therefore, the mechanical properties of the materials must be known. The values realized must be dependable. The design allowables must be chosen from guaranteed strength values. Generally, a 90% probability strength value for the sandwich facings is satisfactory. On the other hand, the adhesive and the core must permit the facings to attain this 90% probability strength if the sandwich structure is to meet the design requirements.

The relative ease and low cost of fabrication, the maintenance of mechanical properties at elevated temperatures and the use of non-strategic materials make glass reinforced plastic sandwich structures attractive. Although the development is still in its early stages, a wide variety of parts such as antenna housings, thermal insulators, control surfaces and other experimental structures are being fabricated on a prototype basis. It is anticipated that industry-wide production on a limited scale will follow depending upon the outcome of extensive proving-out tests.



***PHENOLIC-BASE SANDWICH** structure shown here is composed of a honeycomb core sandwiched between plastic laminate facings. Supported adhesive tape (glass fabric carrier) bonds facings to core.*

Test Methods

In general there are three places where a sandwich structure can fail when subjected to load. These are: 1) the skins; 2) the core-to-skin bonds; 3) the core.

Various tests are available for determining the relative stress levels to which each of the critical areas can be subjected prior to failure. The most important of these methods are:

1. Flatwise shear
2. Flatwise flexure
3. Flatwise compression
4. Flatwise tension
5. Edgewise compression

The Forest Products Laboratory, Madison, Wis., has developed these tests and prescribed recommended procedures (see F.P.L. Report No. 1555, Sept. 1950 and F.P.L. Report No. 1556, Feb. 1950). Since the test methods are at room temperature some modifications will be necessary for elevated temperature performance.

Graphitization in Steel

In designing steel parts or equipment which will operate in the 800 to 1200 F temperature range, the engineer must consider the problem of graphitization. Fortunately, this failure-producing phenomenon can be avoided in several ways.

by **A. M. HALL,** Chief, Alloy Development Div., Battelle Memorial Institute

What It Is

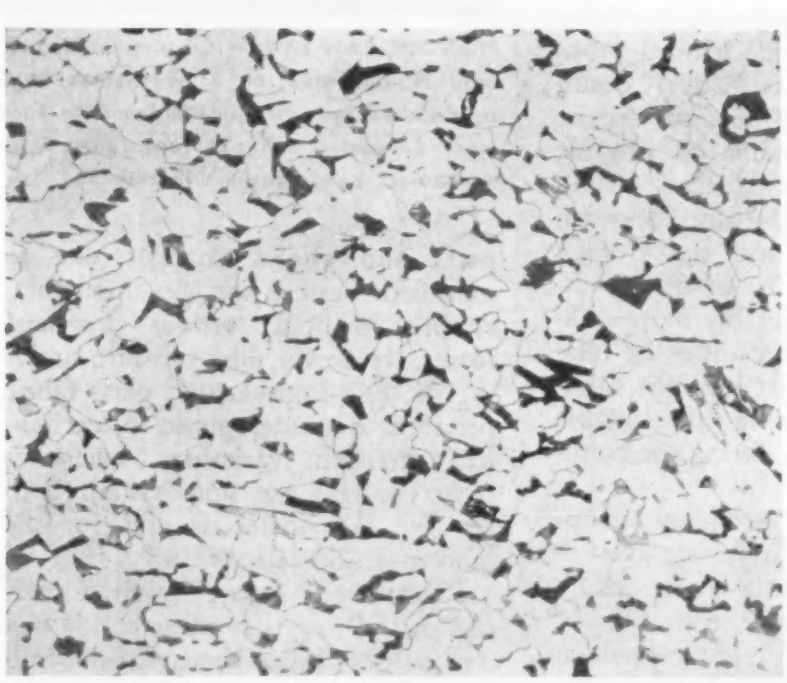


Fig 1—Microstructure typical of hot-rolled steel. The light background is ferrite. The darker areas are pearlite.

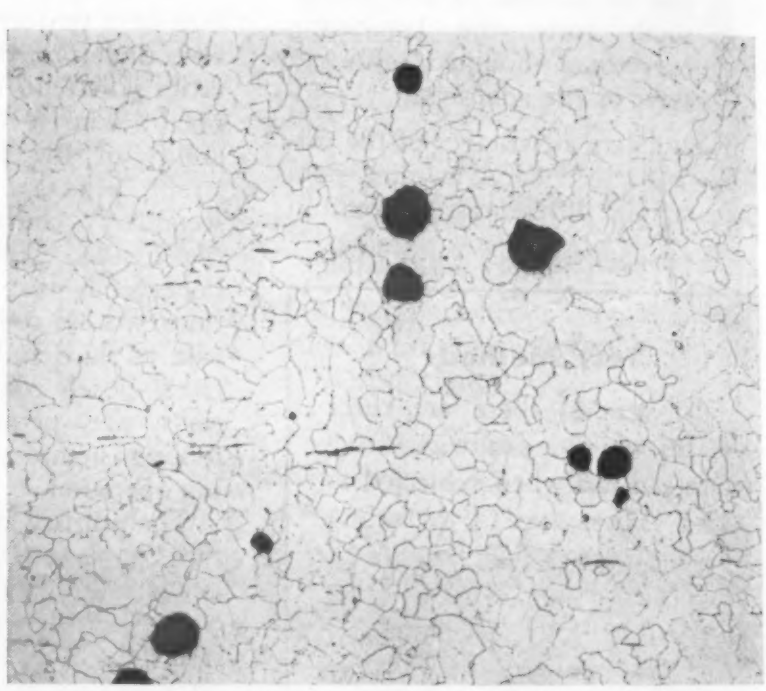


Fig 2—Graphite formation in steel. The light background is ferrite. Dark masses are graphite.

Most unhardened structural and engineering steels are normally made up of two microstructural components. The principal component is ferrite (iron), a soft, ductile metal of relatively low tensile strength. The other constituent is cementite, which is iron carbide (Fe_3C), a hard, brittle compound. Steel derives its combination of strength and toughness from the mixture of these two constituents. The function of the carbon in steel is to provide it with cementite. A normal steel structure as seen with the microscope is shown in Fig 1.

While steel is normally a mixture of ferrite and cementite, this mixture is thermodynamically unstable. Given the opportunity, i.e., prolonged exposure at elevated temperatures, the cementite will decompose into its elements, iron (ferrite) and carbon. The latter will take the form of graphite, which is soft and weak. The steel will then be converted from the thermodynamically unstable mixture of ferrite and cementite to the thermodynamically stable mixture of ferrite and graphite. The process of this conversion is known as graphitization. A graphitized steel structure is shown in Fig 2.

How It Damages Steel

There are two principal types of graphitization. The first, called random graphitization, is the formation of graphite distributed uniformly throughout the steel. In this case, the cementite is replaced by the weaker constituent, graphite, which results in a reduction of the room-temperature mechanical strength of the steel. This loss in strength, usually, does not affect elevated-temperature service where the phe-

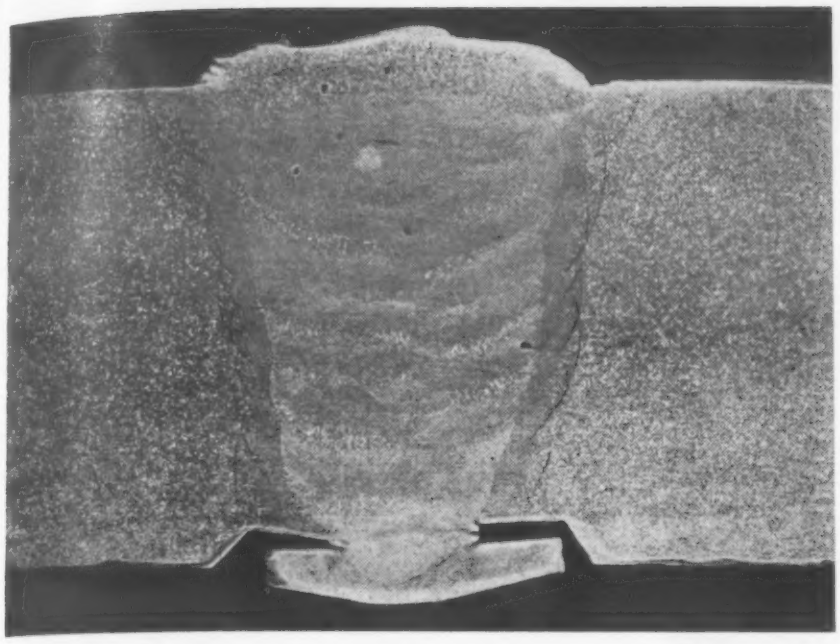


Fig 3a—Graphitization of welded carbon molybdenum steel piping. (Pittsburgh Piping and Equipment Co.)

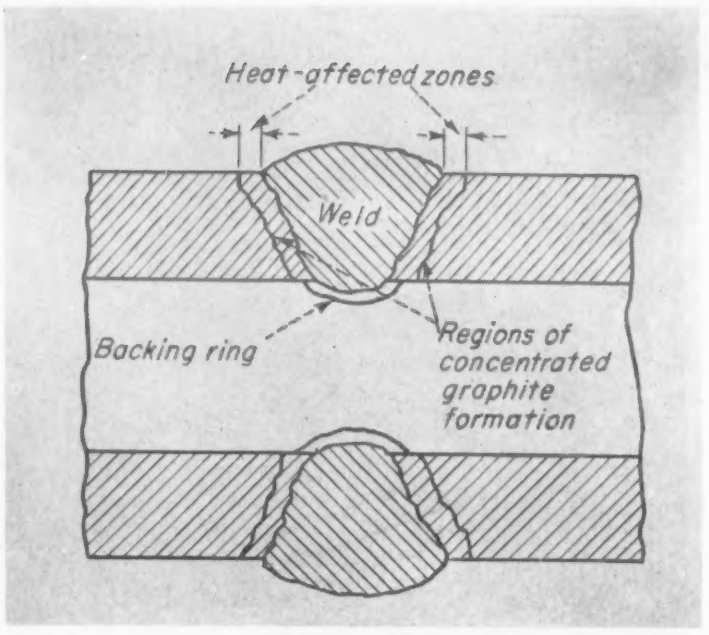


Fig 3b—Schematic longitudinal median section through a single-V butt-welded pipe joint.

nomenon of creep is dominant in establishing the service performance.

In general, the creep resistance of the steels under discussion depends upon the characteristics of the ferrite, which are not changed in the graphite-formation process. Therefore, in many engineering applications, the general effect of random graphitization might not be important.

The second type is the formation of graphite in local and highly concentrated regions. When this occurs, it is reasonable to anticipate ultimate mechanical failure, as long as the conditions permitting graphitization continue to exist.

The most frequently encountered form of localized graphitization is that which occurs near a welded joint. Nodules of graphite form preferentially in a narrow zone which corresponds to the low-temperature edge of the region of the parent metal that was heat affected during the welding operation. In multi-pass welded butt joints, such as are commonly made in thick pipe or plate, the zones of parent metal, heat affected by each pass, overlap each other all the way across the section. The pattern formed is shown schematically in Fig 3. At the low-temperature edge (Ac_1 isotherm) of the weld-heat-affected zones, shown in Fig 3, the number of graphite nodules per unit volume may be so great that they can ultimately grow and link together in a fairly continuous form, as illustrated in Fig 4. Thus, by the process of localized graphitization, a narrow zone extending entirely through the section can be converted from strong steel to weak graphite. Because the graphite cannot take the loads designed for the steel, failure through such a zone can be expected.

Another form of localized graph-

A Broken Joint that Raised Some Questions

In January 1943, a steam pipe line at the Springdale station of West Penn Power Co. suddenly broke near a welded joint. The line, made of carbon-molybdenum steel pipe, had been in operation for the previous 5½ years at an average temperature of 935 F. Fortunately, the boiler was going off the line when the break took place and pressure was falling rapidly, so no serious damage occurred. This sudden and unexpected failure touched off a whole series of investigations through the power industry and its suppliers.

What had happened to the pipe line, in operation so long, to cause this unforeseen failure? The phenomenon of graphitization had taken place in the steel and had occurred in such a manner as to produce a weak, brittle zone in the pipe near the weld.

Soon after the investigations were under way, it was found that graphitization was occurring to a greater or lesser extent in the steam lines of numerous other power stations which were operating at steam temperatures in the same range as the Springdale station. In fact, in one midwestern station, the phenomenon had proceeded almost to the extent found at Springdale, but the condition was discovered before actual failure occurred.

Actually, while the incident at Springdale represented the first known failure due to graphitization, it was not the first time the phenomenon had been encountered in a steel structure. The first recorded instance occurred in petroleum-refining equipment and was reported in 1935. The carbon-steel still tubes of a thermal-cracking unit were found to have graphitized after long service at elevated temperatures. This apparently was an isolated case and it was not until the development of the catalytic cracker that conditions favorable to graphitization were frequently encountered. As a result, several serious cases of graphitization have appeared in the reactor vessels and piping of cat crackers.

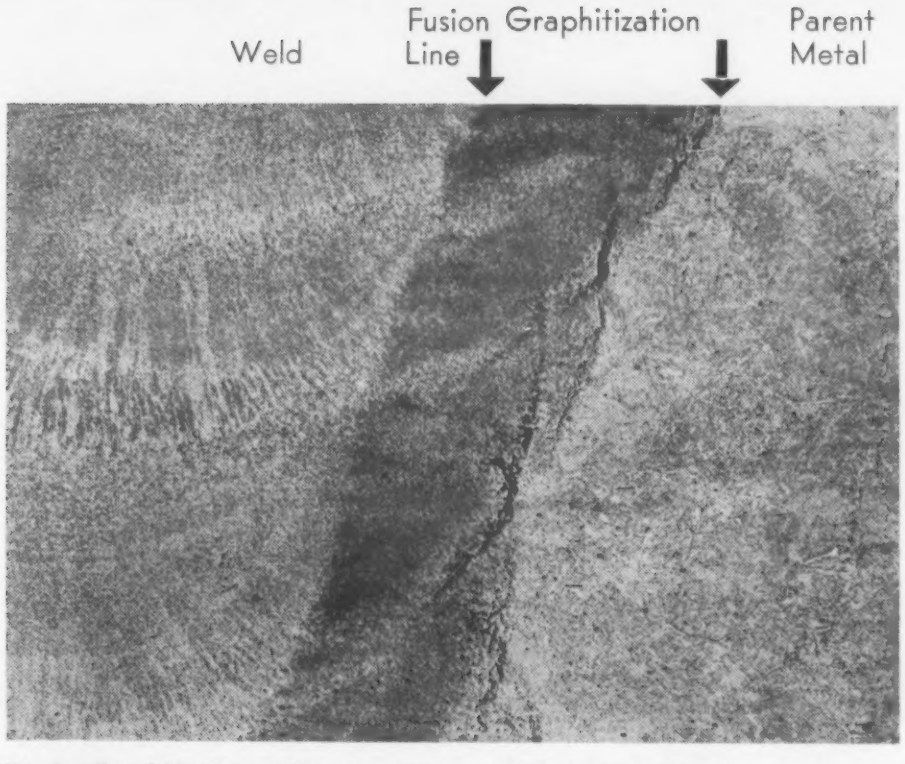


Fig 4—Graphitization at low temperature edge of heat-affected zone of a welded pipe joint.

itization has been observed. This type originates in planes of localized yielding in the steel, called Luder's lines. These lines may be developed during cold forming of the steel, such as bending.

Much remains to be learned about the ways in which highly localized concentrations of graphite impair the mechanical properties of steel. Certainly, the presence of such formations reduces the effective load-carrying cross section. In addition, it is probable that localized graphite provides "notches" which concentrate stress, thereby further reducing load-carrying ability, lowering fatigue resistance and ductility.

When It Forms

The thermodynamics of the process are quite clear, but the mechanism is not well understood. It appears, however, that the graphitization process falls into the class of "nucleation and growth" reactions. In order for the cementite to decompose into graphite nodules and iron, nuclei upon which the graphite can deposit and grow must be present or must form. The growth of the graphite nodules in the steel mass takes place by the diffusion of carbon atoms through the ferrite lattice. In this way, the carbon migrates from the locality of the decomposing cementite particles and deposits on the growing graphite nuclei.

Steels containing the necessary nuclei or in which the nuclei form rapidly are considered to be susceptible to graphitization. If considerable time is required, running to several thousand hours, for the development of nuclei, the steel is classified as moderately resistant. Those steels whose nucleation time is indefinitely long are considered, for practical purposes, to be completely resistant to graphitization.

Once graphitization has begun in a steel, it continues to completion, other things being equal. Reaction curves like those shown in Fig 5 can be drawn plotting the course of the process as a function of time at temperature. In the early stages, the reaction rate is relatively high, but it tapers off as the process nears completion.

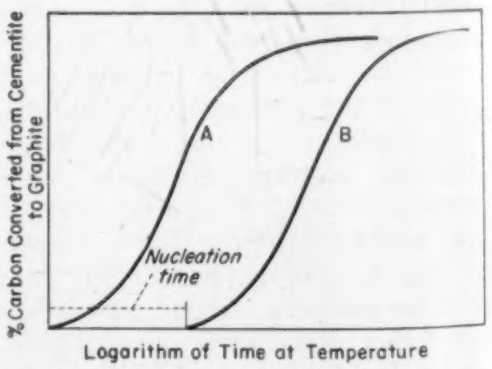
Like all other chemical reactions, the graphitization process is strongly influenced by temperature. Even in highly susceptible steels, it takes place at extremely low rates below 825 F. As temperature is raised above this point, the reaction occurs with increasing rapidity until a maximum is reached in the range of 1150 to 1200 F. At higher temperatures, there is reason to believe that graphitization proceeds more and more slowly and probably ceases to occur above 1350 to 1400 F.

Of great importance is the difference in the inherent susceptibility to graphitization that is displayed by various types of steels. These differences have been found to depend on the composition of the steel and the steel making practice. For example, plain-carbon and carbon-molybdenum steels deoxidized with relatively large amounts of aluminum (1½ lb or more per ton) are susceptible to graphitization. Those deoxidized with small amounts of aluminum (½ lb per ton or less) are more resistant to graphite formation. Silicon-killed steels are more resistant to graphitization than are aluminum-killed steels. Carbon-molybdenum steels seem to be somewhat less susceptible to graphitization than are plain-carbon steels. Chromium, when added in amounts greater than ½%, produces a steel highly resistant to graphitization. In fact, experience obtained thus far indicates that this element imparts immunity to graphitization, for all practical purposes.

The constitution of a graphite nucleus is still a matter of speculation. It had been thought that particles of alumina might act as nuclei. However, susceptibility correlates, not with alumina content, but with "soluble aluminum" which could be present in the steel in solid solution, in the cementite, or as a nitride. Investigation indicates that the soluble aluminum does not partition in the cementite, but suggests that it removes nitrogen from solid solution by forming aluminum nitride.

It would appear that a susceptible steel contains little or no dissolved nitrogen. Both carbon and nitrogen dissolve interstitially in ferrite, i.e., between the normal lattice sites of the iron, and in only small proportions. Each would, therefore, impede the diffusion of the other through the ferrite. However, in the absence of dissolved nitrogen, carbon would have much greater freedom to migrate and assume favorable nucleation configurations.

Kanter has pointed out that there is considerable evidence that plastic straining of the ferrite greatly in-



Idealized reaction curves for the graphitization process.

Curve A—for very susceptible steel.

Curve B—for a moderately resistant steel.

creases the probability of nucleation, perhaps because a disturbed lattice tends to increase the mobility of the carbon as well as to favor formation of the required nucleation arrangements. He has suggested that this may explain why the low-temperature edge of the zone in the parent metal which is affected by the heat of welding is especially favored for the formation of concentrations of graphite. This region is placed under a high degree of localized strain by the allotropic transformation which the steel undergoes during the welding operation.

How To Prevent It

For the power industry, a good answer is to use steels which are not susceptible to graphitization. The trend in this industry, since the demand is for ever higher steam temperatures, is to abandon the plain-carbon and carbon-molybdenum steels in favor of chromium-molybdenum steels which have thus far proved to be immune to graphitization. The industry is taking the position that it is a sounder policy to use chromium than attempt to obtain graphitization resistance by special deoxidation practice, the benefits of which are uncertain. In addition, for long service at 950 F and above, it is advisable to take advantage of the increased oxidation resistance given the steel by the presence of chromium.

For the petroleum-refining industry, the answer is not clear cut. No failures definitely attributable to graphitization have occurred in the industry. Furthermore, investigations currently underway have not progressed to the point where the extent of the damage likely from graphitization can be evaluated. Until this is done a definite procedure cannot be established. As a preliminary guide, it is suggested that a maximum metal temperature in excess of 800 F be avoided, when the equipment is constructed of plain-carbon steels. This can probably best be accomplished by means of internal insulation. Otherwise, chromium-molybdenum steels should be considered. However, when such steels are used, close attention must be paid to welding techniques. These steels are not easy to weld, especially in large sections in the field.

A table contains a partial list of ferritic steels for high-temperature service. These data are offered as a guide to the use of the steels where service conditions suggest that difficulties due to graphitization might be encountered. It is recommended that, when metal temperature exceeds 900 F and service time is long, steels containing more than ½% chromium be used. As stated earlier, the chromium will not only impart resistance to graphitization, but will also increase oxidation resistance, an important consideration since scaling becomes a problem when metal temperatures approach 1000 F for plain-carbon steels.

Much work, both in the laboratory and in the field, has been carried out in an effort to heat treat welded joints of susceptible steels to prevent localized graphitization in the weld-heat-affected zones. To this end, two types of postweld heat treatment have been developed. One is a high-temperature stress-relieving treatment carried out in the range 1300 to 1425 F. The other is a normalizing treatment, usually at 1650 to 1750 F. Data on the efficiency of such treatments are conflicting. However, it seems established that post heating a welded joint in a graphitization-susceptible steel retards, but probably does not prevent, localized graphite nodules in the parent metal adjacent to the weld.

In building new equipment for use under conditions which could produce graphitization, the designer can readily solve the problem by the selection of the proper steel. However, in the case of old equipment in which graphitization can be expected, the problem faced by the operator is not so simple.

No nondestructive testing procedure is available for determining the occurrence of graphite in steel, nor is there any other type of test that can be used in the field. In order to detect graphitization and to determine the extent to which it has progressed, it is necessary to examine samples taken from the equipment in question with the microscope. Bend or tensile tests, or even stress-rupture and fatigue tests, may also be required in some cases.

In the inspection of equipment to detect graphitization, the samples should be selected from those locations where the thermal and stress conditions appear most severe. In welded structures, the heat-affected zones adjacent to the welds are the most likely locations for concentrated graphitization. Trepanned plugs or boat samples are normally taken from such locations for examination.

Suggested Temperature Limits for Various Steels to Avoid Serious Graphitization

Form	ASTM Spec.	Type of Steel	Suggested Max Metal Temp., F
Pipe	A-106	carbon steel	800
Pipe	A-335, Grade P1 (formerly A-206)	carbon, 0.5 Mo	875
Pipe	A-335, Grade P3	1.75 Cr, 0.70 Mo, 0.60 Si	900 and above
Pipe	A-335, Grade P36	2.00 Cr, 0.55 Mo	900 and above
Tubing	A-213, Grade T12	1.00 Cr, 0.55 Mo	900 and above
Tubing	A-213, Grade T22	2.25 Cr, 1.00 Mo	900 and above
Tubing	A-213, Grade T21	3.00 Cr, 1.00 Mo	900 and above
Plate	A-285	carbon steel	800
Plate	A-201	carbon-silicon steel	800
Plate	A-204	carbon, 0.5 Mo	875
Plate	A-301, Grade B	1.00 Cr, 0.55 Mo	900 and above

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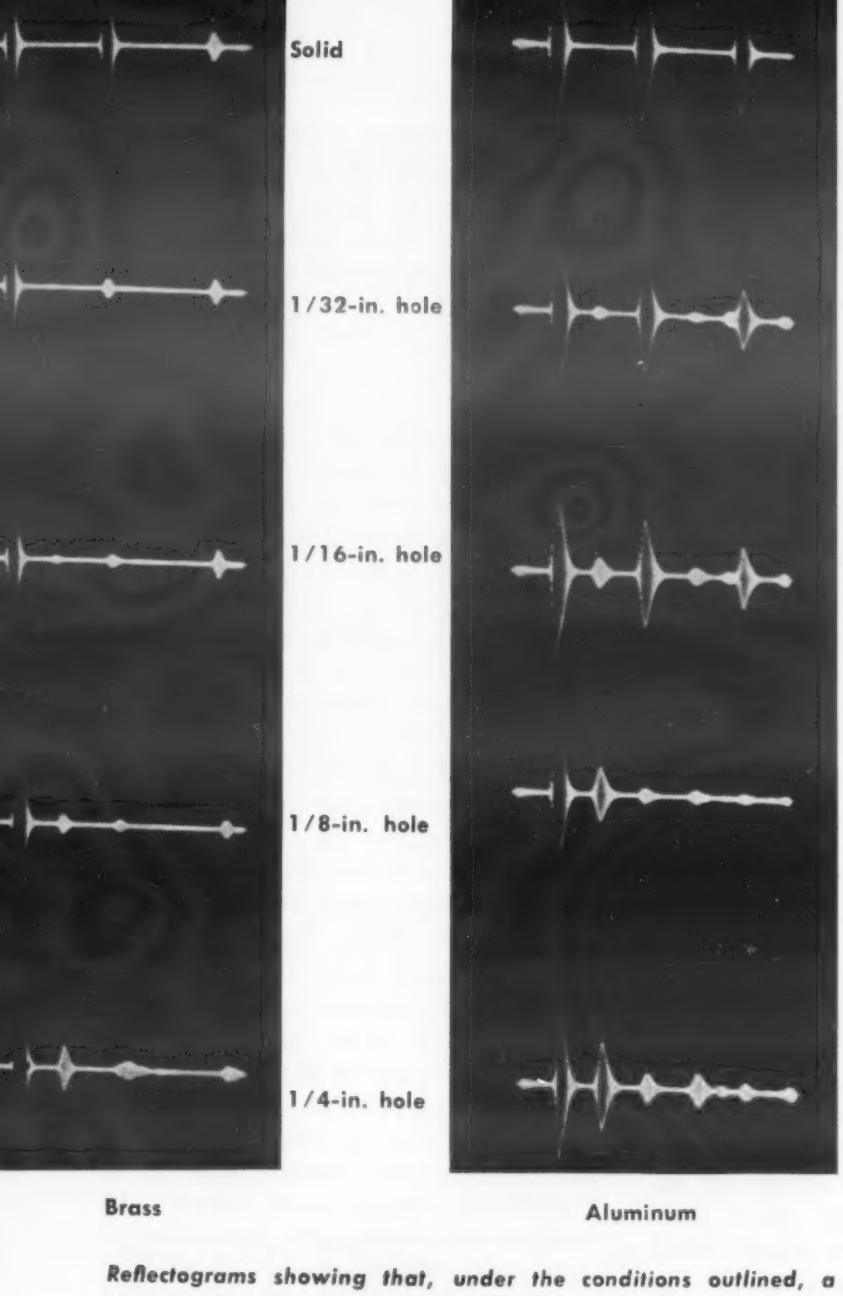
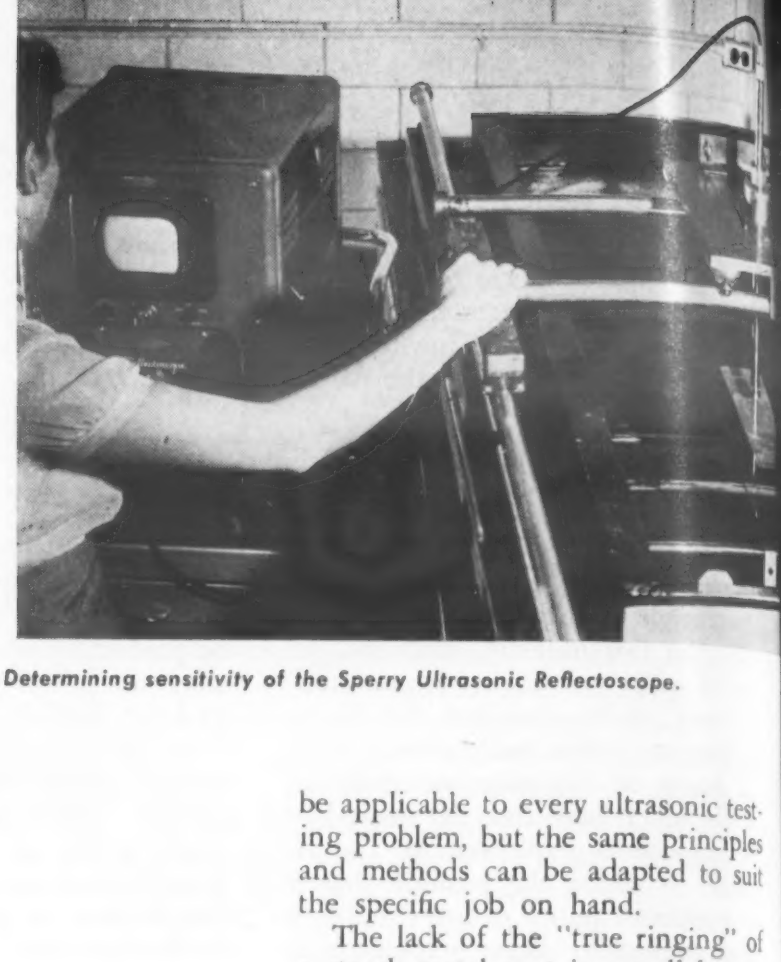


Reflectograms showing that, under the conditions outlined, a flat-bottomed 1/32-in. hole can be detected in brass and aluminum.



Determining sensitivity of the Sperry Ultrasonic Reflectoscope.

How to Check Accuracy of Ultrasonic Flaw Detection

Reference blocks provide a direct and simple method of setting ultrasonic inspection equipment to detect flaws above a specified minimum size.

by NICHOLAS GROSSMAN,
Section Head, Atomic Energy Div., Sylvania Electric Products, Inc.

● AIRCRAFT INDUSTRIES use ultrasonics to examine large slabs of aluminum prior to machining in order to detect and locate internal flaws; foundries check castings where tightness in service is important; railroads periodically check moving machinery parts in order to prevent fatigue failures. In all of these and similar applications, the question arises, "How sensitive is my ultrasonic test instrument in detecting flaws?"

The employment of reference blocks is a simple and speedy method of determining the smallest detectable void, under a given set of conditions. This technique may not be applicable to every ultrasonic testing problem, but the same principles and methods can be adapted to suit the specific job on hand.

The lack of the "true ringing" of a struck metal part is a well known shop method for the detection of gross internal flaws. A refinement of this principle is the utilization of mechanical sound waves above the audible range. These mechanical pulses which vibrate faster than 20,000 cycles per sec are called ultrasonic waves.

Several commercial ultrasonic instruments are on the market. These instruments can detect blowholes or porosity in castings, laminations in forgings, inclusions of foreign particles in metallic and nonmetallic materials, as well as internal cracks in parts and structures. The principle of detection is always the same: any discontinuity which causes an ultrasonic mismatching for the traversing waves gives an indication. It is the job of the testing engineer then to interpret these indications and set up procedures and standards.

In evaluating the sensitivity of a given ultrasonic test unit, it is important to keep the following variables in mind: 1) the instrument and its power input; 2) the frequency of the waves; 3) the size and shape of the search crystal; 4) the contacting medium; 5) the chemical composition, metallographic structure, mechanical properties, and geometry of the samples; and 8) synthetic defects used for comparison.

In the present tests, commercial practices were followed whenever feasible. A frequency of 10 mc was selected because tests showed that the shorter waves are more sensitive in detecting small defects. The accompanying table lists the smallest de-

Reflectoscope Settings

Material	Frequency mega-cycles	Sweep length*	Reject	Pulse length*	Marker	Pulse Tuning*	Sensitivity*
Brass	10	2½	off	1	off	⅓	6
Aluminum	10	1	off	1	off	⅓	3⅓

NOTES: Face of search unit 2¼ in. above top surface of specimen.
Sweep delay adjusted to obtain 3 reflections on scope.
** Arbitrary settings. These enable inspector to adjust equipment after optimum settings have been established.*

Smallest Detectable Flat-Bottomed Hole, in.

Frequency Megacycles	Material	
	Brass	Aluminum
1	1/16	1/16
2¼	1/16	1/32
5	1/32	1/32
10	1/32	1/32

NOTE: Depth of hole ¾ in.

tectable flat bottomed defect when lower frequencies are used. The reference blocks were machined from regular production materials to eliminate variables which might result from the use of general test blocks, unrelated to the specified materials (see details at right).

Procedure

The Sperry Ultrasonic Reflectoscope, Model UR, was used. This instrument has constant operating frequencies of ½, 1, 2¼, 5 and 10 megacycles per second. It can be used with any commercial search unit which generates longitudinal, shear, or surface waves, has a built-in sweep delay, and is designed for either one or two crystal operation.

The circular quartz crystal has a ⅜-in. effective aperture, is designed for 10 mc frequency, and is properly grounded and waterproofed for immersion testing. Immersion testing was selected because factors such as surface finish, contact pressure, area of contact, do not influence the results, and therefore the tests are more reproducible and thus more reliable. The search unit is mounted in a suitable scanning device.

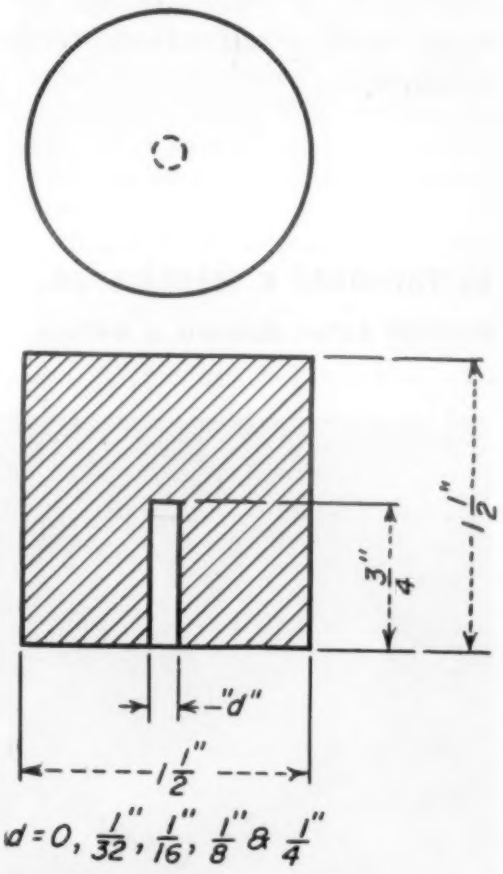
The actual testing consists of placing the cylindrical specimens in the tank so that the holes are facing the bottom. To prevent trapped air, and air and water mixtures in the holes, they are filled with wax prior to submersion. Since wax readily absorbs ultrasonic waves it does not interfere with the indications of reflected waves from the metal surfaces. Using the single crystal, pulse-echo testing technique the crystal is then moved to obtain optimum reflection; that is, the axis of the beam and the axis of the specimen coincide. Reflectoscope settings are listed in a table.

To obtain a permanent record of a test, the oscilloscope indications called reflectograms are photographed. The reflectograms shown in a figure indicate that, under the conditions outlined, a flat-bottomed 1/32-in. hole can be detected both in brass and in aluminum. In general, the detection of a void in aluminum requires less sensitivity than in brass. This results from difference in acoustic impedance of the two metals, the value for brass being more than twice that for aluminum. (See accompanying box).

No tests were performed for detecting holes smaller than 1/32 in. in diameter. However, the method is applicable to any size or shape of defect that needs to be simulated in order to establish the limit of sensitivity of the testing set-up.

The depth of the hole, which is ¾ in. and the height of the rods, was kept constant during the tests. The depth was chosen as a matter of convenience and has no special significance. As long as the total metal thickness to be penetrated by the sound waves permits ready transmission and reflection of these waves in a given homogeneous metal structure, the depth of the hole in the reference block has no specific effect on sensitivity. This is also true for a similar actual defect in the slab or plate to be tested, provided the defect is not adjacent to one of the metal-water interfaces.

Reference blocks can provide a direct and simple method for setting the Reflectoscope to detect flaws above a given predetermined minimum. The "Reject" knob or the "Sensitivity" knob can be so adjusted as to give indications to flaws equivalent or greater than the permissible minimum determined by the product and materials engineer.



Reference blocks were produced from commercial brass (ASTM B-16) having a hardness of Rockwell B 72 and 2024-T4 aluminum having a hardness of Rockwell B 76. These blocks were machined cylinders, 1½ in. long, having faces flat and perpendicular to axes. Holes 1/32, 1/16, ⅛ and ¼ in. in diameter bored at axes to a depth of ¾ in. simulated voids. These four blocks together with one prepared similarly but having no hole comprised set used to determine the sensitivity of the instrument.

Acoustic Impedance

The acoustic impedance (R) is a measure of the ease of propagation of the sound waves in an elastic medium. Numerically it is the product of the density of the medium, brass or aluminum, and the velocity of the sound waves in this medium.

For brass,

$R = 0.308/386$ lb sec/in.^{3} x 174,000 in./sec = 138 lb sec/in.^{3}

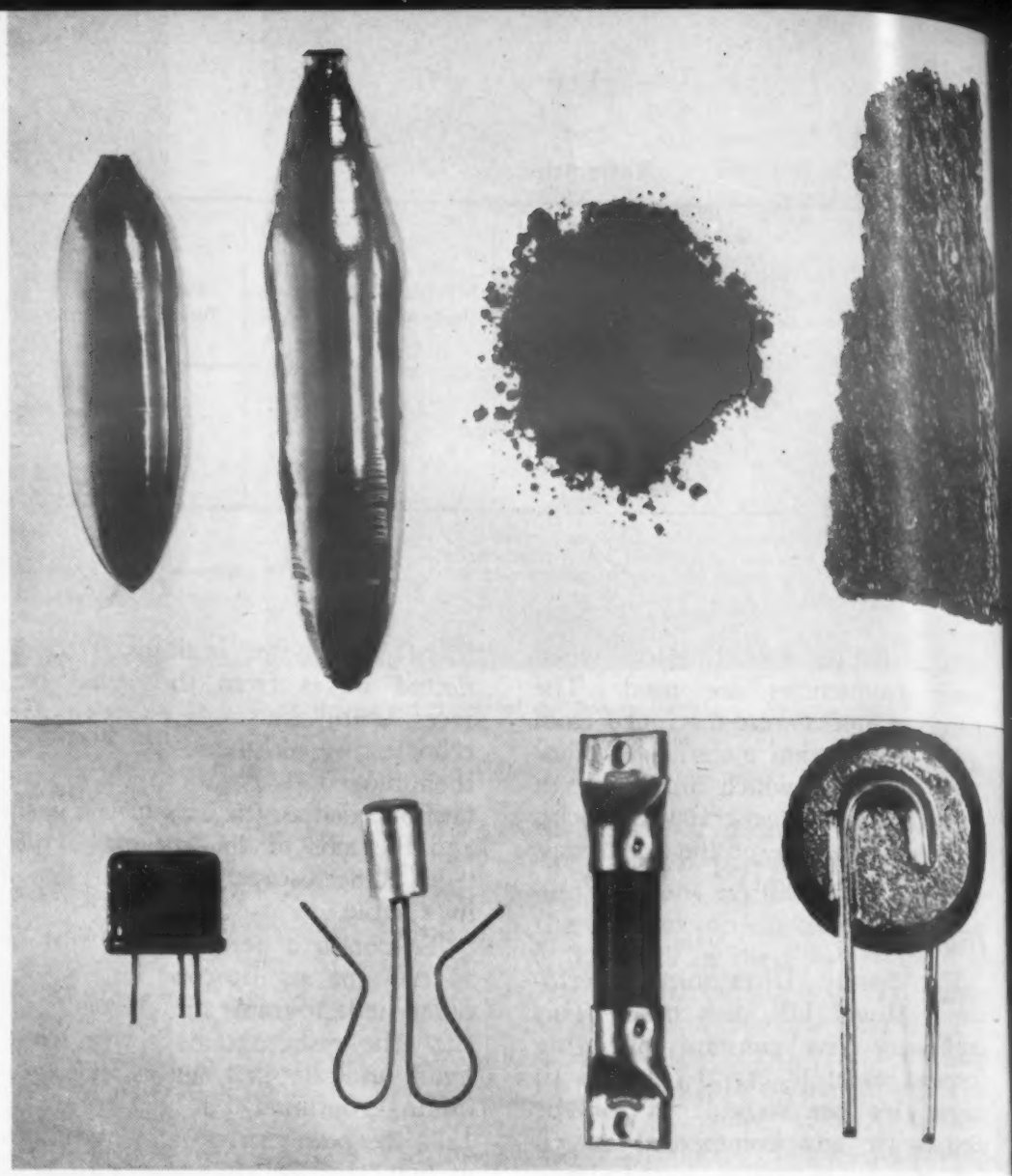
For aluminum,

$R = 0.100/386$ lb sec/in.^{3} x 245,000 in./sec = 63 lb sec/in.^{3}

Thus the acoustic impedance of brass is more than twice that of aluminum. The physical dimensions of the acoustical impedance can also be interpreted as impulse per unit volume, i.e. specific impulse. Thus aluminum has a much lower specific impulse than brass.

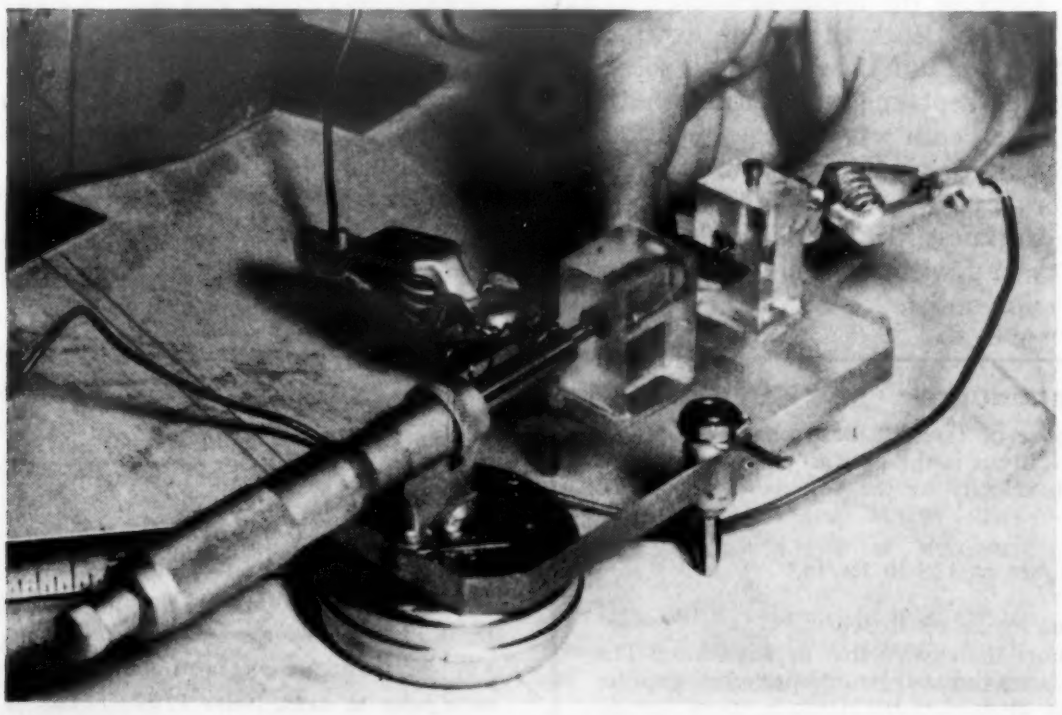
Better Semiconducting Materials → Lead to New, Wider Uses →

The unique electrical properties of semiconductors have resulted in higher efficiencies and new devices in the electronic and power fields. Germanium and silicon leading the way, they are generating broad changes in established design and production techniques.



Semiconducting raw materials are shown with representative devices. Left to right: Germanium single crystal ingot over germanium transistor; silicon single crystal ingot over silicon diode; powder mixture of metal oxides over thermistor; and silicon carbide multicrystalline ingot over symmetrical varistor. Not to scale. (Bell Telephone Labs, Inc.)

by THEODORE B. MERRILL, JR.,
Assistant Editor, Materials & Methods



Cadmium sulfide solar battery is between the plastic mounts. (Air Force Photo)

● SOLID MATERIALS FOR control and generation of electrical current—the semiconductors—are emerging from a period of rapid growth of theoretical and applicational development. They are exerting a compelling influence on the design of electronic and electrical devices, and promise, because of their inherent efficiencies and potential dependability and long life, to broaden the area of application of electronic systems for control and communication.

Semiconducting devices generate or control electrical current within the crystal structure or at the crystal boundaries of a solid element or compound. There is no mechanical motion, no transfer of ions, and no need for a power consuming heat source to provide free electrons. The energy required for control in semiconducting devices may be very

small, and little energy is consumed in the control process. As a result, the efficiency of semiconducting devices is greater, sometimes in order of magnitudes, than standard devices.

Semiconductors perform non-ohmic functions, since their conductivity is non linear in regard to a number of variables, *viz* temperature, incident light energy, electrical field, impurity content, and crystal structure. While each of these variables is useful in some devices, if only one is used all the others must be strictly controlled. Therein lies the problem of all semiconductor applications.

Rectifiers

Semiconductor power rectifiers generally are not used at voltages higher than 200, although when connected in series for low power applications, higher voltages are possible. The disadvantage of elements in series is that the individual resistances build up with a consequent voltage drop. At higher voltages thermionic tubes or ignitrons have good efficiencies. For low voltage applications, semiconducting rectifiers provide high current densities. Copper oxide and selenium rectifiers perform well below 50 v and at temperatures below 150 F. More recent work with silicon and germanium has resulted in the development of efficient rectifiers capable of operating at high power levels in the voltage range between 50 and 200 v.

Westinghouse Electric Corp. has developed practical germanium rectifier units capable of carrying a rated load current of 200 amp at a forward voltage drop of 0.63 v. With these units rectifiers with capacities up to about 6000 amp at 65 v are practical. The rectifying junction itself is a sandwich disk of germanium, tin, indium and molybdenum, about $1\frac{1}{2}$ in. in diameter and $\frac{1}{8}$ in. thick. The semiconducting element in this case must be protected from atmospheric or water vapor contamination, from excessive temperature (150 F max) and from excessive fault currents. Units are either water or forced-air cooled. Since there is an increase in reverse current at higher temperatures, the power limits are determined by the amount of reverse current tolerable. Reverse fault current will destroy the *p-n* junction, as will fault currents over 3000 amp for more than 10 cycles in the forward direction.

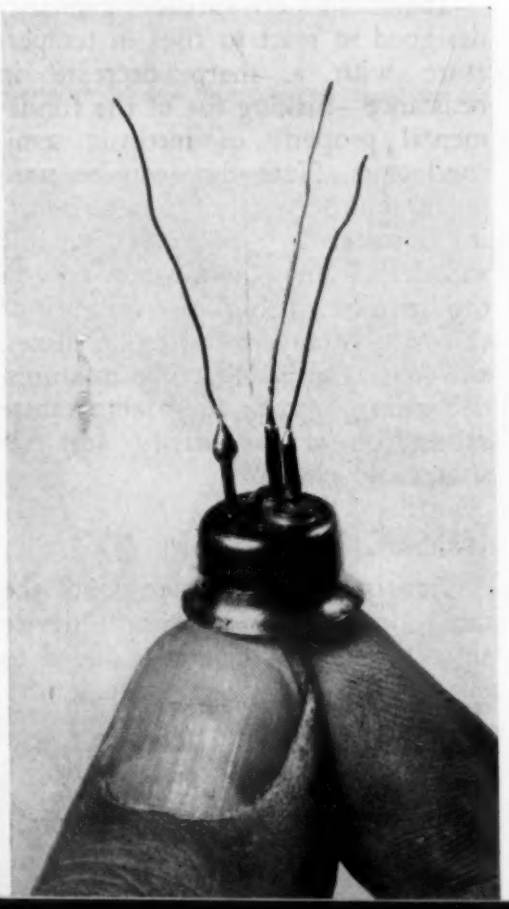
Silicon offers even greater advantages than germanium as a power rectifier material, as units will operate at temperatures up to 300 F. However, at this temperature considerable reverse current results. Westinghouse is presently working on pilot models of air cooled 200-amp silicon rectifier tubes which are expected to perform with high efficiency on medium voltage electrochemical and 250-v industrial service.

Bell Telephone Laboratories has developed a "diffused junction" silicon rectifier cell which will also tolerate temperatures up to 300 F. As a power rectifier the unit operates with an efficiency of 95%, with the power loss almost entirely attributable to forward drop since the reverse currents encountered are negligible. The diffused junction is produced by heating a slab of single crystal silicon (doped to *n*-type) in the presence of the vapor of a donor such as phosphorus on one side and an acceptor, such as boron, on the other. This produces a layer of high conductivity doped silicon of controlled thickness on both sides of the slab, with a *p-n* junction slightly below the surface on one side. The highly conductive doped layers simplify the problem of making electrical connections to the slab, and the process has resulted in the development of silicon lightning protectors and solar generators (q.v.) as well as rectifier elements.

Silicon Lightning Arrester

Bell Telephone Laboratories' low loss silicon lightning arrester is similar to the rectifier cell, but with *p*-type layers on both sides of the *n*-type silicon slab. The unit is highly resistant to voltages of either polarity below its saturation point, which can be varied from 30 to 200 v depending on the amount of *n*-type impurity present in the base material. An experimental unit with 95-v saturation provided a voltage limiting characteristic of a little over 300 v for 20 microsec pulses of 5000-amp. The voltage over saturation is attributed to the resistance of the silicon n-type layer, which amounts to about 0.05 ohms. Barring contamination, silicon lightning arresters should have an indefinite, maintenance-free life.

Power Transistor by Minneapolis Honeywell has an output of 20 w, uses metal chassis as heat sink for cooling.



Solar Generators

In the present state of technology, the only materials which hold promise of converting radiant solar energy to electricity at reasonable efficiencies are the semiconductors. There are now two solar power generator techniques under development: Bell Telephone Laboratories' diffused junction silicon cell and Wright Air Development Command's cadmium sulfide cell. Both cells operate on the principle that light energy will produce hole-electron pairs in semiconductors. These hole electron pairs can be separated at a *p-n* junction and put to work in an external circuit.

Bell Labs.' silicon diffused-junction cell consists of a 0.0001-in. layer of *p*-type silicon formed over an *n*-type base. Maximum voltage developed is 0.5, at which Bell scientists calculate a theoretical maximum efficiency of 22%, although internal resistance, recombination of hole-electron pairs, and contact problems limit efficiency of working models to 8%.

The cadmium sulfide cell is composed of crystalline cadmium sulfide, a semiconductor, in contact with silver, which creates a *p-n* junction. Voltage developed by the cell is linear with the amount of radiation, until a plateau is reached at about 0.6 v. Normal sunlight generates about 0.3 v. Air Force physicists claim the present cells, consisting of a single small crystal, develop about 8% efficiency and have a potential of 20% if a transparent electrode for the ohmic connection to the crystals can be developed. Relatively pure cadmium sulfide crystals are inexpensive, since it is a common compound used as a paint pigment and

sublimates and recrystallizes easily to provide extremely pure crystals up to ¼ in. in maximum dimension. The Air Force has not revealed whether power has been generated in usable amounts from aggregates of cadmium sulfide cells.

Other Photoconductors

Selenium and semiconducting compounds such as lead sulfide are common photosensitive materials which have been used for years in vacuum photocells, lightmeters, and in devices which electronically amplify slight conductivity changes or photogenerated current. Germanium, silicon and cadmium sulfide photocells now in production or under development have much greater sensitivity and operate at power levels suitable for direct operation of relays.

Commercial germanium photocells or phototransistors are much smaller than their vacuum tube equivalents, and require much less illuminated area than selenium cells. The cells are shock-resistant because of the low mass of the germanium element and the small lens opening necessary. Generally, they are sealed in metal tubes behind a glass lens, the whole assembly being about the size of a kidney bean. Such cells are also sensitive to nuclear radiation and can be used as gages or warning devices.

Commercial phototransistors have a light-dark current ratio of about 20:1.

Cadmium sulfide photocells, with a high output are now on the market. One subminiature, ¼ in. by ¼ in. is rated to deliver 2 to 5 ma.

Varistors and Thermistors

Varistor is an inclusive term. It refers to any two terminal, non-linear, non-ohmic semiconducting device. While power rectifiers and lightning arresters are basically varistors, we will limit the discussion here to circuit devices used at lower powers for temperature sensing, equalization, surge elimination and high frequency rectification (detectors).

Copper oxide varistors have been used in telephone circuitry for over 25 years, and the crystal detector of early radio sets is over 50 years old. However, it is only recently that the materials technology of these devices has emerged from "mixing-pot" techniques.

There are two types of varistors: symmetric and nonsymmetric. Symmetric varisitors are non-polar and exhibit the same resistance characteristics in either direction of current flow. Non-symmetrical varistors perform a rectifying function, being more resistant to current flow in one direction than in the other. Non-symmetric varistors will operate symmetrically by arranging two with matched characteristics in parallel with reverse polarity.

Varistor materials include: silicon; germanium; copper oxide; copper sulfide; selenium; silicon carbide; mixtures of the oxides of nickel, manganese, cobalt and copper; and more recently, a host of stoichiometric compounds composed of elements from the third and fifth columns of the periodic table such as gallium antimonide, indium phosphide, aluminum antimonide, indium phosphide, aluminum antimonide, and others.

Germanium point contact varistors, or diodes, are in large quantity production for use in detector circuits. In the forward direction, germanium diodes will pass up to 25 ma at 1 v, while in the reverse direction, biased at 5 to 10 v, they exhibit resistances over 100,000 ohms and frequently up to several megohms. They are capable of handling reverse voltages on the order of 100 v.

Silicon point-contact varistors are used in microwave circuits and have the lowest forward resistance of all types of varistors (in the range of 10 to 60 milliamps forward current at 1 v.), while maximum reverse resistance is developed at a fraction of a volt. Reverse current rises rather rapidly and the unit will be destroyed at reverse voltages of much more than 5 v.

Thermistors are varistors primarily designed to react to rises in temperature with a sharp decrease in resistance—making use of the fundamental property of intrinsic semiconductors. Since they can be nonpolar, multi-crystalline semi-conducting materials provide suitable vehicles. Many thermistors are on the market using a variety of ceramics, ceramic-metal oxide mixes, and other semiconducting mixtures, depending upon the temperature range, power, sensitivity and resistance levels.

Transistors

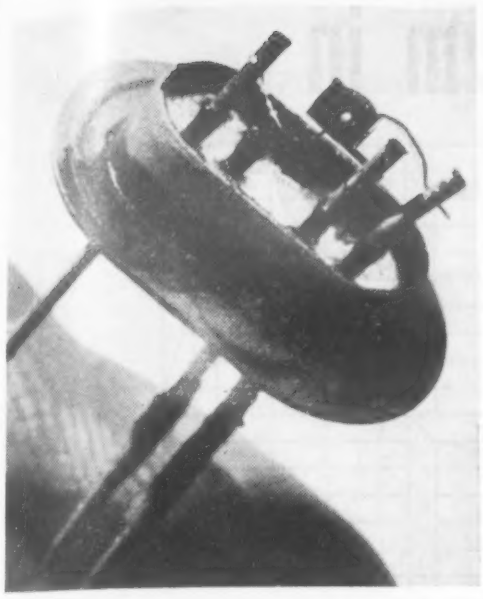
Transistors are without doubt the most important electronic device since the control grid was added to the thermionic tube. From the standpoint of design theory, they will perform all functions of vacuum tubes with the exception of high power applications. From a commercial standpoint, they are in use in switching circuits and in low power audio frequency amplifiers. The gap between theory and application is closing fast due to progressive materials developments. Transistors will be used in devices as their dependability rises, their production problems are solved, and as their price declines.

The basic materials of transistors are ultrapure single-crystal germanium and silicon, carefully doped with proper impurities. To provide proper semiconducting characteristics, these metals are prepared with impurity levels reduced to the order of a few parts per billion. Lead telluride and lead sulfide have recently been claimed suitable as transistor materials.

There are two general types of transistors—point contact and junction. A point contact transistor is basically a small die of doped germanium to which an ohmic contact is made and on which are placed carefully spaced point contacts with rectifying characteristics similar to those in diodes. One point is called the emitter, and serves to inject minority carriers (holes in the case of *n*-type germanium) into the base. The other point is the collector, which can be considered the output lead. Small amounts of injected minority carriers cause large variations in the collector-base current. Thus high current amplification factors (alphas) result. The highest reported alpha for a point contact is 50, which is much too high for most applications, and commercial point contact transistors are usually in the 2 to 3 alpha range.

Junction transistors differ from point contact transistors in that all rectification and control takes place within the germanium or silicon ingot instead of at the surface. There are two types of junction transistors: fused junction, and grown junction.

Grown junction transistors are formed by slowly pulling a single crystal of germanium of silicon from a melt so that the solid-liquid interface is at the surface of the melt. Small quantities of impurities added as the crystal is withdrawn produce a single crystal of successive layers doped to *p*- and *n*-type. The



The tiny square between the leads is the most promising high frequency transistor to date. A p-n-i-p fused-junction transistor such as this has generated frequencies as high as 460 megacycles, or four times that of any comparable triode transistor. (Bell Telephone Labs, Inc.)

ingot is then cut into tiny dice less than 1/8 in. long and about 1/32 in. sq. Each of the dice has three areas, *p-n-p* or *n-p-n*. The *p-n* junctions are almost perfect rectifiers with an area equal to the cross section of the die. As this area is several hundred times as large as comparable point contact areas, junction transistors operate at higher power levels and have considerably lower noise levels than the point contact types.

Junction transistors operate on a similar principle to point contact. In a *p-n-p* junction, for example, the *p*-type layers are separated by a thin layer of *n*-type material. Welded or indium-soldered leads provide ohmic contact to each area. The *n*-type area acts as a base, with two *p-n* junctions separating it from the emmitter and collector sections of the unit. When a bias voltage is applied in the reverse direction from the collector to the base, the *p-n* junction offers high resistance to the passage of current. However, when the emitter section is charged in a forward direction in regard to the base, minority carriers (holes) diffuse across the thin base section and break down the rectifying properties of the base-collector *p-n* junction, allowing current to flow in the base-collector circuit.

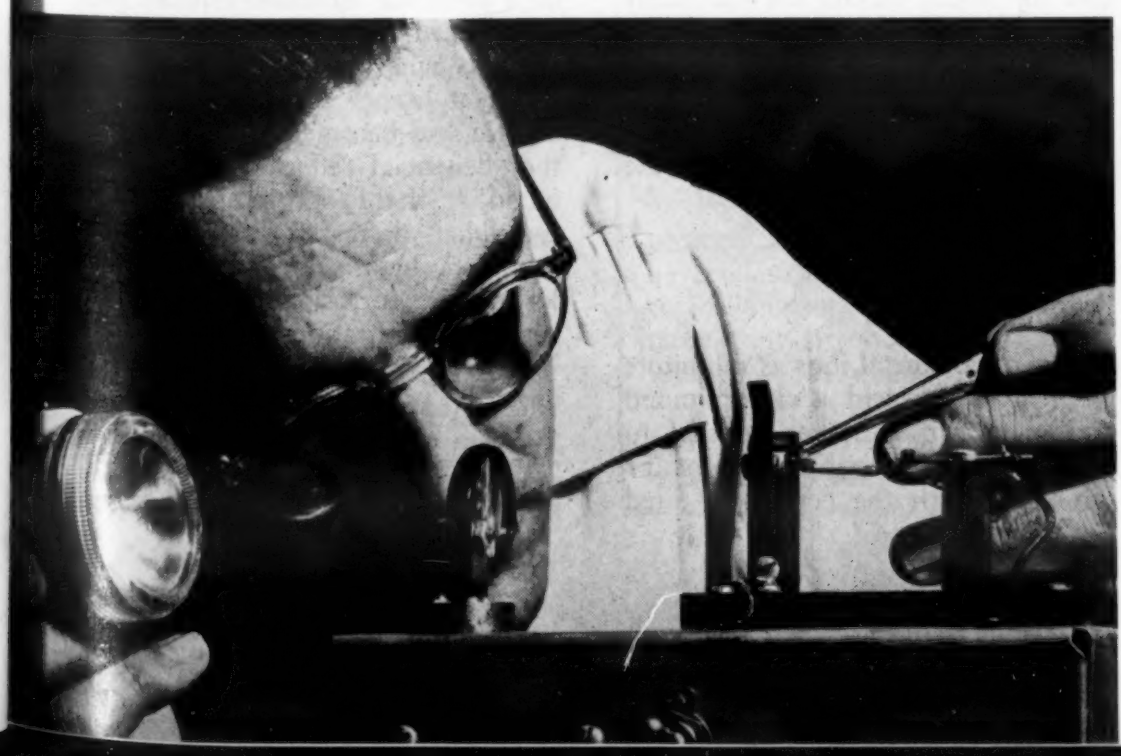
At low frequencies or direct current applications, this process is relatively straightforward, but high frequencies introduce a number of complicating parameters. The closely spaced junctions of either side of the base act as a capacitor and the width of the base causes a time lag due to the finite amount of time it takes holes to diffuse across the base to the collector junction. Thus the maximum frequency cut-off of a junction transistor is a function of the width of the base and the capacitance effects. As the time-lag is also a function of material characteristics, the mathematical expressions for these parameters are complex. However, design theory has been worked out so that given the material characteristics and geometries involved, the maximum theoretical frequency cut off of any junction transistor can be established.

Fused-junction transistors operate on the same principles as do grown-junction, but the fabrication technique differs. The base layer is shaped alone, and doped material is fused on either side of it by plating or indium alloying techniques. The dimensions of fused junctions must be held within millionths of an inch, and base layer thicknesses sometimes are as low as 1/2 micron.

A most promising new development in the fused junction transistor field is the new *p-n-i-p* triod developed by Bell Laboratories. The extra layer denoted by "*i*" is a layer of intrinsic germanium—not doped—and has the effect of lowering base thickness without increasing capacitance proportionately. Theoretical maximum frequency cut off for this configuration is about 3000 megacyles. However, frequency levels will remain far below this until many materials and fabrication problems can be solved. In less than one year, however, the maximum frequency of operation of *p-n-i-p* experimental units has increased from 25 megacycles to over 450 megacycles.

Germanium is extremely sensitive to temperature variation, and its electrical properties change permanently at temperatures greater than 200 F. This limits joining processes and sealing methods to those which are carried out at low temperature. Silicon is not as sensitive to heat but is injured by temperatures much in excess of 350 F. All commercial manufacturers produce germanium transistors exclusively with the single exception of one firm, which also makes a silicon transistor. All germanium transistors have a maximum operating temperature below 140 F. The silicon transistor has raised this maximum to 210 F. Both semiconductor materials are extremely sensitive to water vapor and must be sealed off from atmospheric contamination to the extent that extreme precautions are necessary to avoid sealing atmospheric water vapor or other impurities in with the semiconducting material, or allowing it to seep in along the leads.

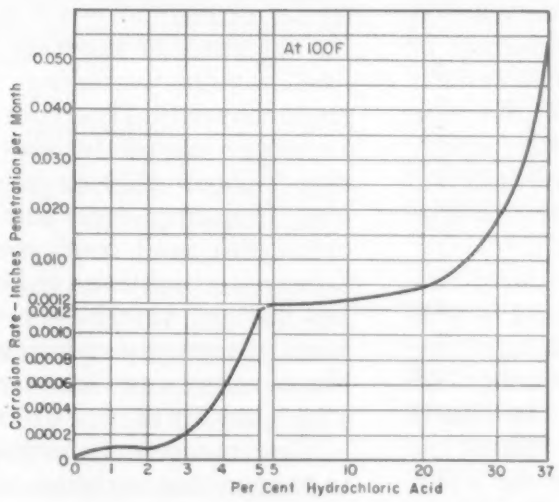
Germanium phototransistor being assembled by General Electric technician is sensitive to many types of radiation.

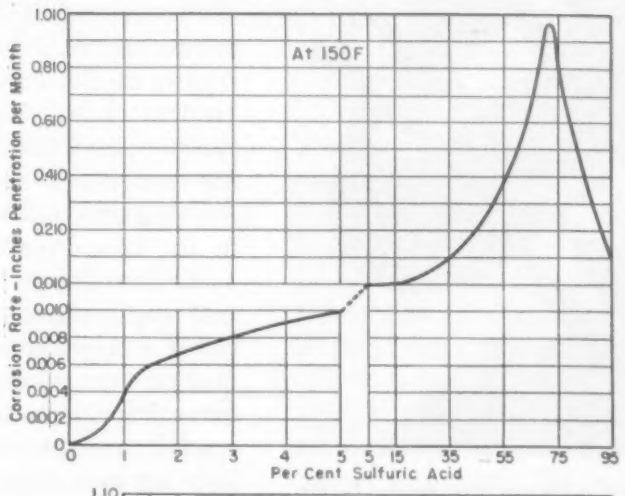


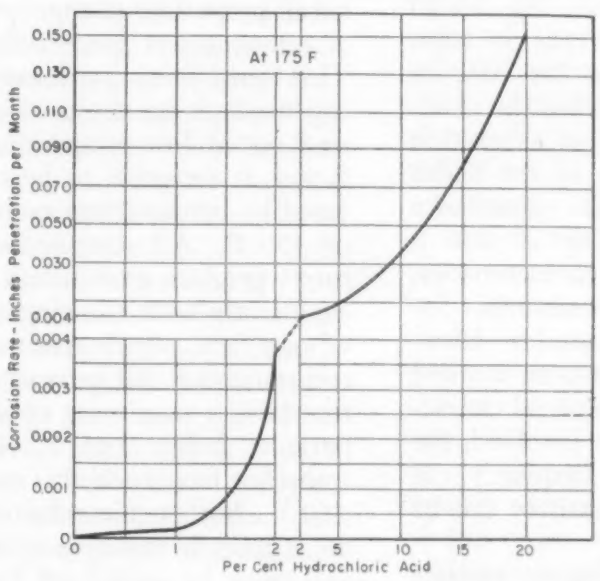
Materials Research Advanced

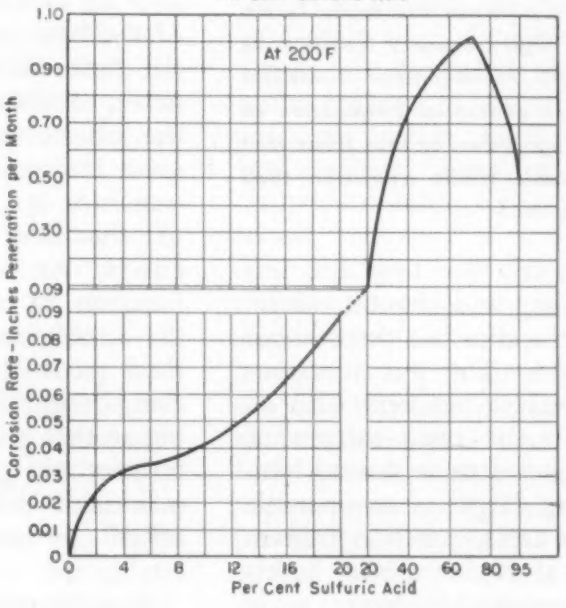
The research on semiconducting materials is more important, in an over-all sense, than the implications it will have for the future of electronics. Knowledge of the basic structure of materials has been broadened, particularly in the field of crystallization. Industry has gained this knowledge, not through the happenstance of empirical mixing-pot techniques, but as a result of following a well-defined path from conceptual theory to experimental verification to practical application. Scientists consider many of the original technological and research papers in the field of semiconductors as "classic"; yet the ink is hardly dry. In all probability, the whole history of the development of semiconductors will become a classic pattern in the relationship of pure research to applied technology.

Corrosion Resistance of Titanium in . . .









Hydrochloric Acid

Corrosion rates of titanium are considerably lower than those for many other common metals. Above charts show corrosion rates in various concentrations of hydrochloric acid at four different temperatures.

The resistance of titanium to hydrochloric acid is much better than its resistance to sufuric acid. Unlike the behavior in sulfuric, titanium appears to have a rather definite active-passive boundary condition in hydrochloric acid, remaining passive in acid up to about 3½% at 100 F, 1½% at 150 F, 1¼% at 175 F, and 1% at 200 F. The corrosion rate rises quite rapidly after the metal becomes active and slight breaks occur in the curves at about 2% at 100 F, 2% at 150 F, and 4% at 200 F. No appreciable break was found at 175 F and the curve shows a continuous rise after the samples become active.

The rates in hydrochloric acid are appreciably lower than in the corresponding concentration of sulfuric acid and in contrast to the behavior in sulfuric acid no decrease in corrosion rate occurs in concentrated hydrochloric acid.

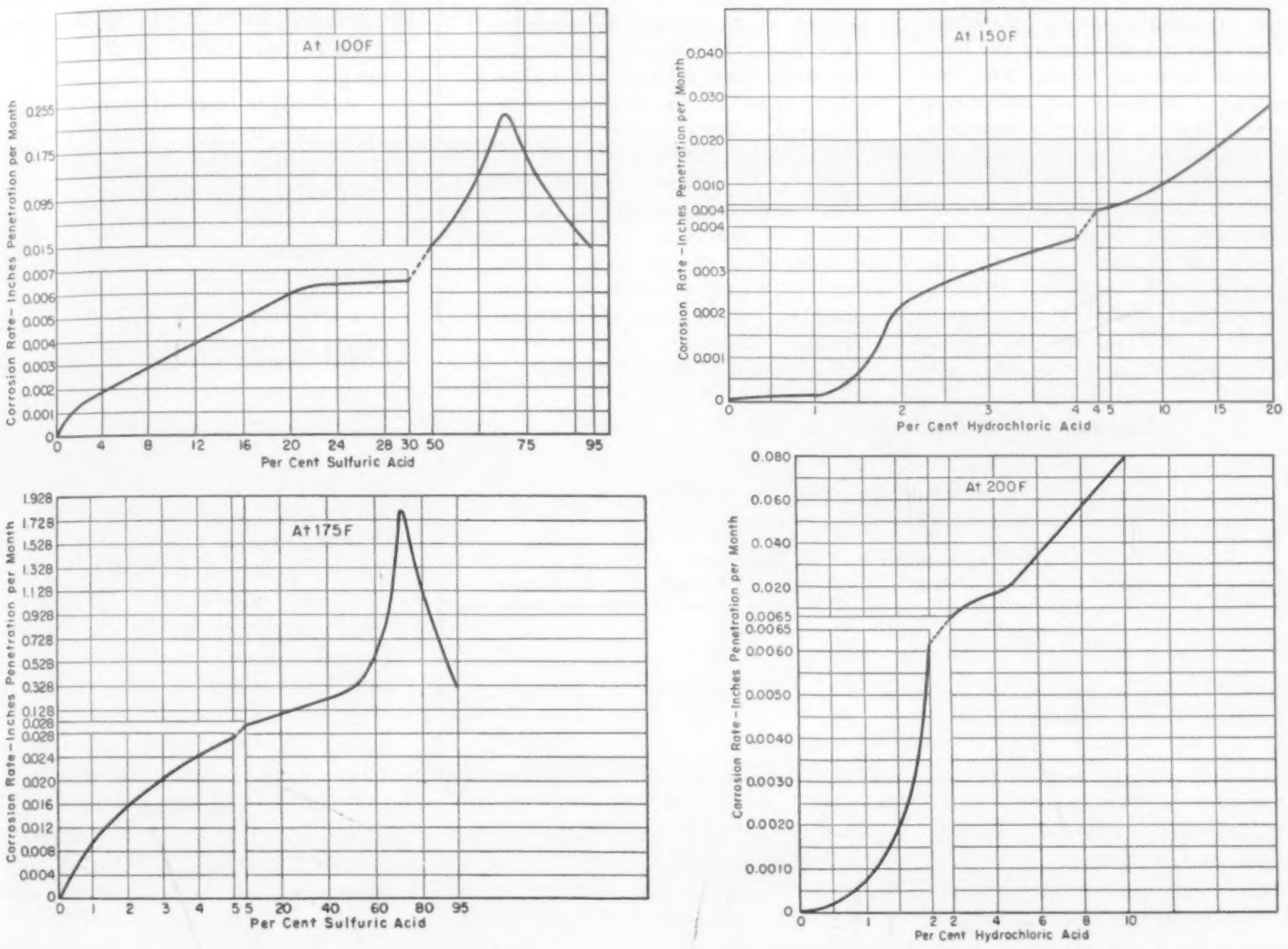
Although the passive range of titanium in hydrochloric acid is very narrow, the metal still shows rates which are considerably lower than those shown by many other common metals and alloys. Because only a few of the high nickel-base alloys and the noble metals are extremely resistant to hydrochloric acid and most other metals show very little or no resistance to the acid, titanium appears to have very good resistance to moderate concentrations of the acid.

Effect of Additions to Hydrochloric Acid

The use of metal ions as inhibitors for hydrochloric acid is rather limited and in fact it is rather unusual to obtain any appreciable amount of inhibition with the commonly used inhibitors. Thus, in contrast to the behavior of most metals and alloys, titanium, while rapidly attacked by 35% hydrochloric acid at 100 F, is almost completely resistant to a mixture of 3 parts of hydrochloric to 1 part of nitric acid (commonly known as aqua regia). Actually the effect of a particular addition is more pronounced in hydrochloric acid than in sulfuric acid at the lower temperatures; at higher temperatures hydrochloric acid becomes more active and the beneficial effect of additions noted at the lower temperatures is somewhat decreased. The rates in inhibited hydrochloric acid are as low as the corrosion rates found in certain concentrations of sulfuric acid.

The investigation with both acids was conducted for the Titanium Metals Corp. of America.

by **WARREN W. HARPLE, Allegheny Ludlum Steel Corp.***



Sulfuric Acid

In many ways, titanium exhibits corrosion properties similar to such metals as stainless steels, copper and nickel. Above charts show corrosion rates of titanium in various concentrations of sulfuric acid at four different temperatures.

Tests in pure sulfuric acid solutions indicate that titanium behaves differently from the passive alloys, such as the stainless steels, and from such metals as copper or nickel which show reasonably low and constant corrosion rates at all except very high concentrations. However, in many respects, titanium probably exhibits properties of each of the above mentioned metals.

For example, although some titanium has shown a narrow passive range at very low concentrations and temperatures, this particular heat showed no definite passive zone in dilute acid at low temperatures. Instead, the corrosion rates appear to increase gradually as the acid concentration increases from 0%. There is no region where the rate of attack is constant and almost negligible, and there is no abrupt rise in corrosion rate at some limiting concentration which distinguishes the change from a passive to an active state.

While titanium has a definite passive state in many corrosive media as shown by its generally good corrosion resistance, results here indicate that apparently even in dilute sulfuric acid the conditions are unable to maintain a passive state. As all specimens employed were activated before testing, the inherent ability of the metal to become passive must be assisted by the envionment itself. As pointed out by Kiefer and Renshaw, the oxidizing ability of sulfuric acid is very slight at low acid concentrations. Probably the oxidizing power of the sulfuric acid is not sufficient to promote passivation of titanium in many cases, especially with a wealth of hydrogen ions available which are tending to activate.

In spite of the fact that the metal shows an active condition at acid concentrations as low as 0.5% the corrosion rates in percentages even up to 10% at 100 F are not too high to rule against its use for many commercial applications. Other metals which do not exhibit any passive state in sulfuric acid are frequently employed for such applications

Corrosion Data Relative

Commercially-pure titanium, while essentially free from any detrimental impurities, varies considerably, from heat to heat, in the amount of trace elements present. Since these elements can have considerable effects on the corrosion properties, results obtained in corrosion studies are relative and should be used merely to indicate the general behavior of the material in a corrosive environment.

* *Now with Mathieson Chemical Co.*

Testing Procedure

In carrying out this corrosion study every effort was made to provide a uniform testing procedure. Tests were run on samples cut from a single sheet of Type 75A. Preliminary potential measurements showed that an activating treatment in a 50% by volume solution of hydrochloric acid at 150 F produced a fairly constant active potential. Therefore, all samples were immersed for five seconds in the hydrochloric acid activating solution, water rinsed and then immediately placed in the sulfuric or hydrochloric acid testing solution. Tests were carried out in duplicate for a two-hour period in beakers submerged in a constant temperature water bath. In preparing solutions, chemically pure sulfuric and hydrochloric acids and distilled water were employed; reagent grade chemicals were used for the inhibitors.

While the corrosion rate of some other metals may be affected by the amount of dissolved oxygen in the solution, data in the table indicate that the degree of aeration is not significant in the case of titanium. Consequently all tests were made in non-aerated, non-agitated solutions.

Corrosion in Sulfuric Acid at 100 F

Acid %	Rate in In. Penetration per Month			
	As mixed	Air bubbled through	Hydrogen bubbled through	Deaerated
2	0.001	0.001	0.002	0.001
4	0.002	0.002	0.002	0.002
10	0.003	0.004	0.003	0.003

where corrosion rates of similar magnitude are shown.

As acid concentrations become higher, the hydrogen ion concentration approaches a maximum at 30% by weight and then decreases with further increases in acid concentration. It might be expected that the corrosion rates would tend to rise proportionally to a similar maximum at 30%, since the metal is always in the active state. However, other factors than hydrogen ion concentration alone must be involved in the dissolution of the metal. The corrosion losses do not consistently rise at the same rate. For example, at 100 F the curve is essentially a straight line up to 30% where it changes slope. Above 30% the slope increases quite sharply. The curves at higher temperatures show similar characteristics.

Titanium is no different from other metals in failing to show a maximum at 3%. The gradual rise in corrosion rates up to about 30% indicates a behavior somewhere between that of ferrous metals and a metal such as copper.

Above 30% at 100 F, the straight line characteristics are no longer present, and titanium shows a rapidly rising curve up to a maximum of 70% sulfuric acid. Copper and nickel show their lowest corrosion rates through this region, due to the minimum solubility of oxygen in about 70% acid, but titanium shows its highest rates in a manner similar to ferrous metals. Since the maxima shown by mild steel, stainless steel and titanium fall at 47%, 60% and 70% respectively, it is probable that complex chemical reactions within the acid itself are taking place, and the products of these reactions have widely different effects on the three metals. Titanium is like ferrous metals in this acid concentration range.

Beyond 70% the decrease in corrosion rate might be expected because of the low degree of ionization in concentrated sulfuric acid. Titanium is attacked at an appreciable rate by concentrated (95%) acid even at 100 F, in spite of the very low hydrogen ion concentration. At 95% acid, very strong oxidizing conditions are present which would be expected to be beneficial in promoting a passive condition. Mild steel and stainless steel both show excellent corrosion resistance in concentrated acid due to the formation of protective corrosion products on the surface. Indications are that in the case of titanium the oxidizing conditions do not prevent attack and in this respect the metal is similar to copper. The corrosion products formed at this concentration apparently are fairly soluble or are not especially protective in nature against further attack. Furthermore, the corrosion rates at 95% are always higher than those in the transition range.

Although tests in pure acid solutions indicate that titanium has many characteristics of nonpassive metals, additions of salts and oxidizing agents to these solutions tend to disprove this fact in the 5% to 30% sulfuric acid range.

Effect of Additions to Sulfuric Acid

A series of different sulfates was added in small amounts to 5% sulfuric acid at the four temperatures. It was found that the presence of added sulfates materially lowers corrosion rates in 5% sulfuric acid. As the temperature increases, the effect of these added salts becomes less pronounced, with the exception of copper sulfate. At 100 F nickel sulfate and copper sulfate are the most effective in inhibiting attack, followed in decreasing order by tin (stannous) sulfate, ferrous sulfate and sodium sulfate.

In 30% sulfuric acid the addition of small amounts of chromic acid or copper sulfate, both strong oxidizing agents, is sufficient to produce passivity of the metal. It would appear that titanium belongs to the passive class of metals, since it is so definitely affected by additions of oxidizing agents. However, 30% pure acid was indicated as the transition concentration above which the metal assumed characteristics of the ferrous metals.

While there are many voids in the data which must be filled to obtain a more positive picture, sufficient information has been obtained to indicate trends. Behavior of titanium in pure acid solutions shows characteristics somewhat different than would be expected of a passive type alloy. At certain concentrations a very marked resemblance to nonpassive type metals such as nickel was observed. However, additions of salts or oxidizing agents have passivating effects which would be encountered only with alloys of the passive type.

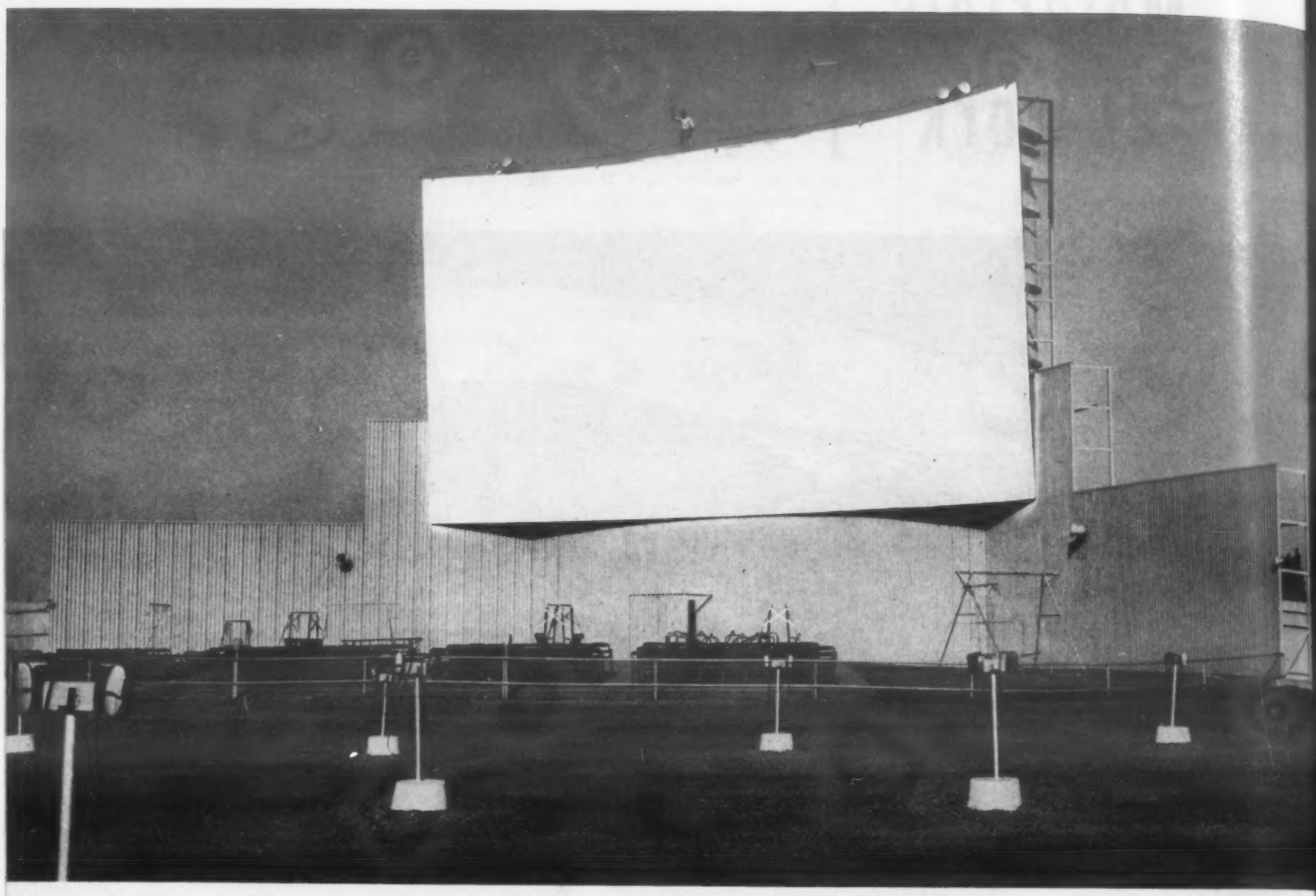
Until more is known about the actual relationship between the structure of titanium and its behavior under different solution conditions, the various theories of passivity applied to other metals and alloys can be equally well applied to titanium.

Materials at Work

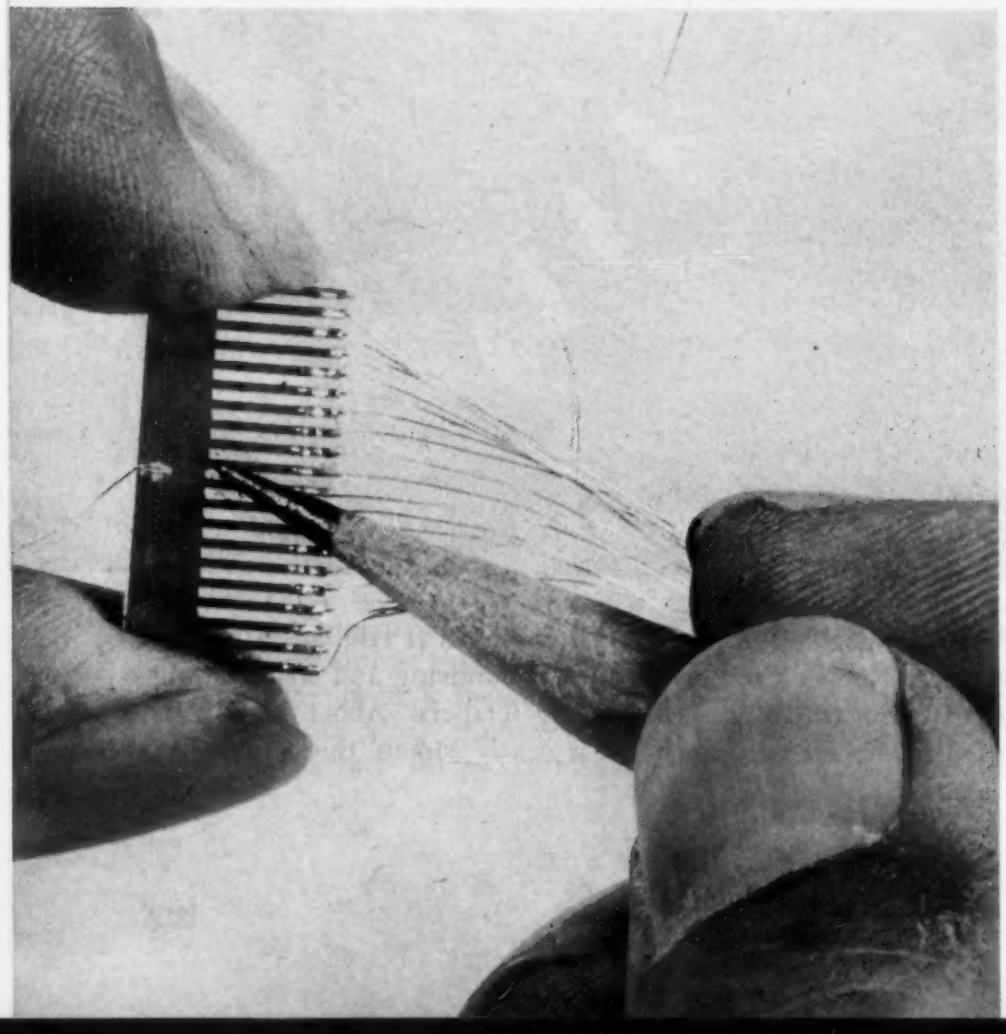
Here is materials engineering in action . . .
New materials in their intended uses . . .
Older, basic materials in new applications . . .

Jumbo Rubber Tire Weighing 2600 lb and standing 8 ft tall, this 30.00-33 tire is made by U. S. Rubber Co. for use on earth-moving and strip mining equipment, bottom dump trucks and self-loading scrapers. About 2 miles of bead wire are used in the tire, and the tread is nearly 3½ in. thick.

Materials at Work

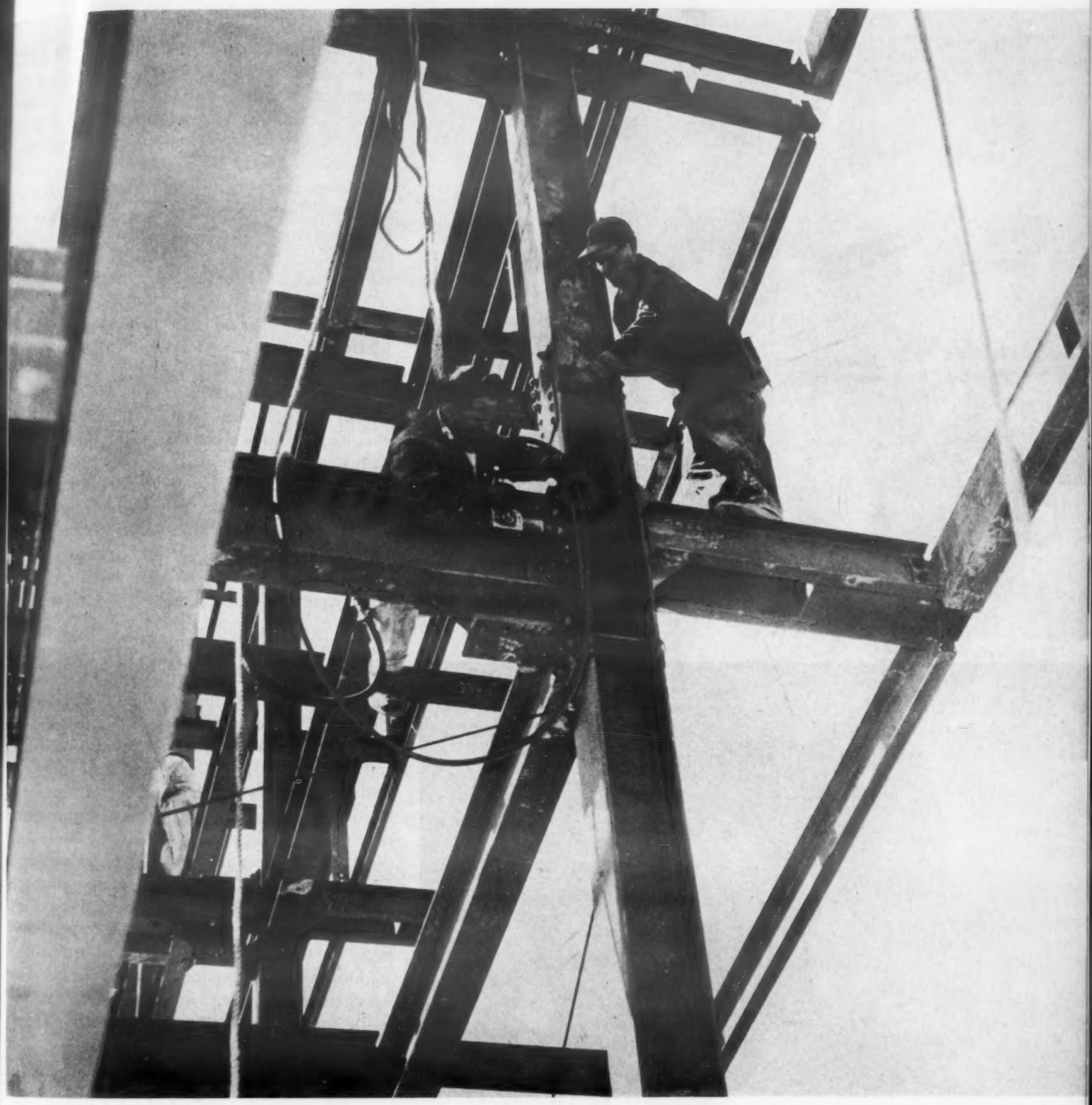


Reinforced Plastics at the Flickers This screen for a drive-in theater is made of plastics reinforced with Owens-Corning glass fiber. The screen measures 80 by 40 ft and is curved for the radius of light projection. It is supported by a 2 by 2 by ¼-in. angle iron frame.



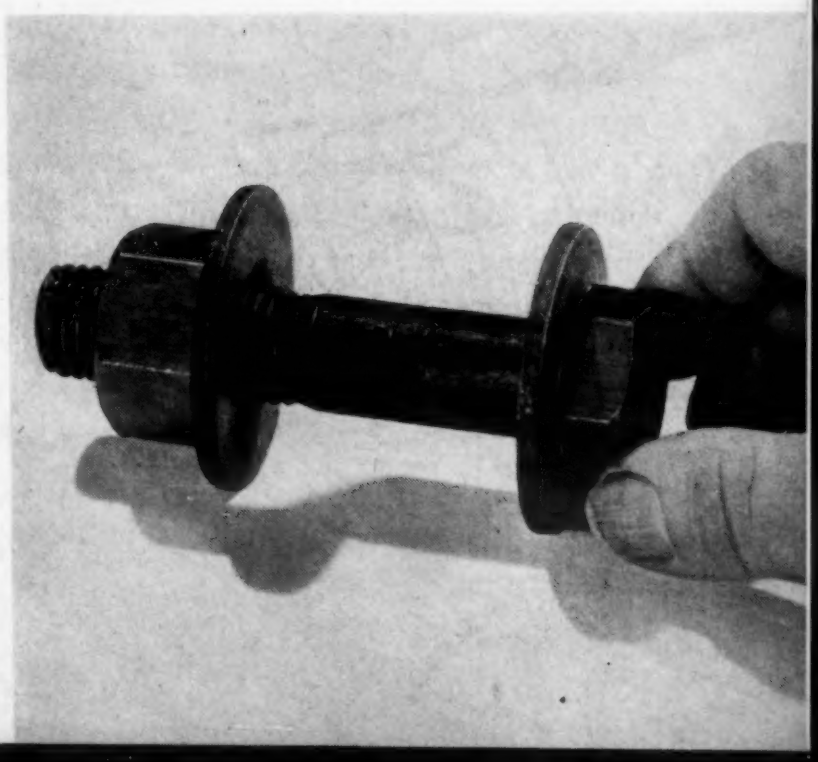
Tiny Glass Photoconductors Slips of glass, coated with lead sulfide, that are 10,000 times as sensitive to certain infrared rays as previous laboratory instruments, have been produced by the Eastman Kodak Co. Known as Ektron Detectors, the devices are expected to find wide application in instruments which operate by detection of warm objects in their immediate vicinity or over long distances. Though the cell reaches its peak of sensitivity in the invisible heat rays of the near-infrared, it is said to be highly sensitive to all colors of visible light and to ultraviolet.

In addition to its possibilities for heat detection devices and for replacement of "electric eyes", the company expects applications to be found in the automatic control of chemical processing plant operations and in electrical equipment where mechanical switching devices are bulky, impractical or unreliable.

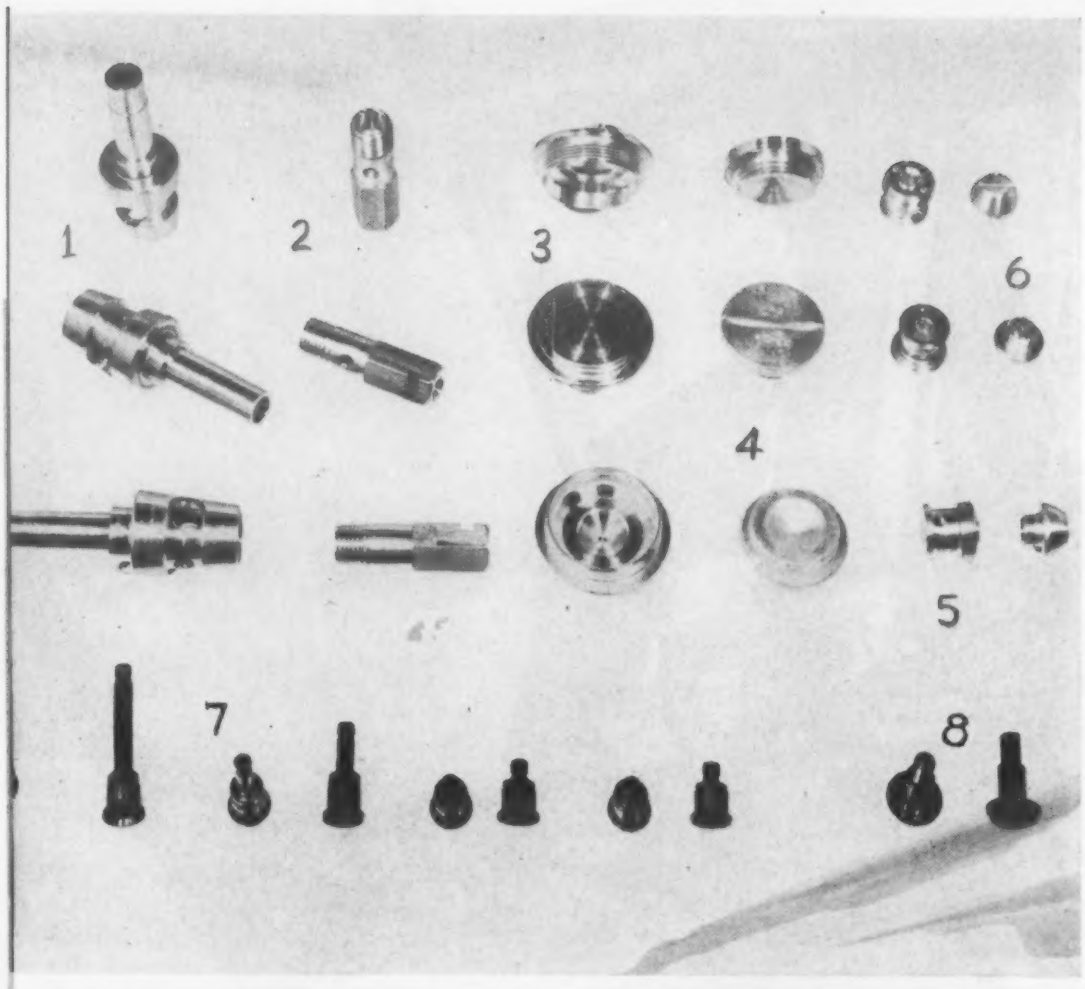


Bolts and Nuts for Skyscrapers The high strength bolt method of joining structural steel in skyscrapers is becoming more and more widely used. The bolts are said to be easier and safer to install and provide as much or more strength to the joint as conventional riveting methods.

U. S. Steel Supply Division of U. S. Steel Corp. and Lindberg Steel Treating Co. have developed successful heat treating methods for the washers, which enable them to transmit the clamping force of the nut and bolt without gouging or scoring, and to provide the ductility to form with the steel members.



Materials at Work



Switch from Copper to Aluminum Cuts Cost

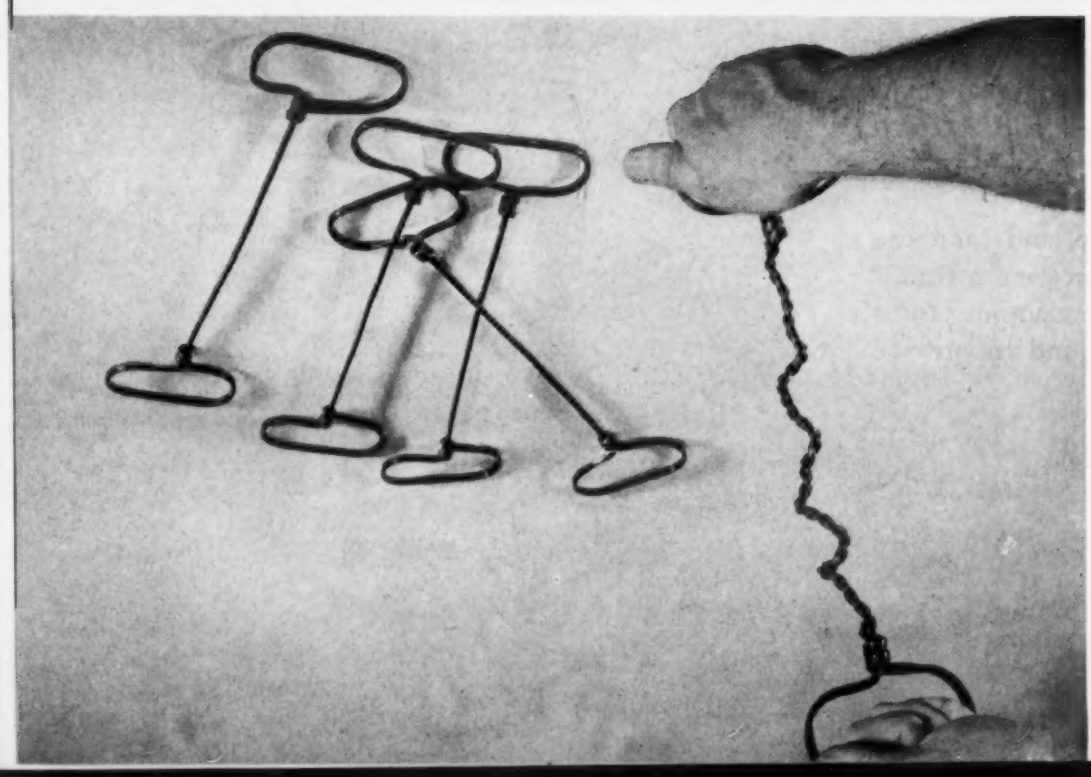
A switch from copper and copper alloys to aluminum for these basic elements of control devices manufactured by Robertshaw-Fulton Controls Co., has resulted in substantial cost reductions. The major factor bringing about this lower cost was the reduction in weight of the material. Though the aluminum material is more expensive than the copper, the weight differential allowed reductions in the cost of the materials shipments, and in the shipping cost of the finished devices.

Additional advantages were obtained for several of the components through 1) the ability of aluminum to hold grease at 250-350 F temperatures better than the brass previously used; 2) improved machinability of the aluminum; and 3) resistance of aluminum to corrosive attack of gases, particularly sour gases.

Parts shown are: 1—gas cock plug for gas range oven thermostat; 2—pilot body; 3—magnet type cap for gas water-heater controls; 4—filter type cap for gas water-heater controls; 5—pilot valve insert; 6—pilot valve cap; 7—orifice spuds; 8—dial screw.

Aluminum-Ferrous Bond Aids Cooling of Generator

The Al-Fin method of bonding aluminum to ferrous alloys is being used to speed heat exchange in this liquid-cooled aircraft generator. The pre-formed steel tubes for coolant oil and stator lamination stackings are bonded to the light metal by the Al-Fin method developed by the Fairchild Engine and Airplane Corp. This intermetallic bond provides a high degree of heat dissipation into the aluminum. The heat is then carried away by the coolant circulating through the coils. Shown here are the preformed tubes and lamination stacking after application of the bonding coat which is the first step in the process. At left is the finished bimetallic casting.



Rectangular Copper Wire Coated With Film Insulation

An increase in the reliability of transformers is said to have resulted from the development of a film coating which will not peel or chip from the corners of rectangular copper wire. The film, called Formex, is applied to the wire by a method developed by the General Electric Co.'s Distribution Transformer Dept. and it is also said to allow reduction in transformer sizes and weights. The copper conductor is given 5-8 separate coats of the film, each of which is baked. According to the company, 3 mils of Formex film has a higher insulation value than 5-7 mils of paper or paper-and-cotton insulation.

Adhesive bonding can be accomplished by a number of different methods: spatula (top), pressure bonding (left), brush (center), spraying (right), and tape (bottom). *(Curtiss-Wright Corp., Consolidated Vultee Aircraft Corp., Minnesota Mining and Manufacturing Co.)*

Adhesive Bonding

by HELMUT THIELSCH, Grinnell Co.

There are at least 24 different types of structural adhesives in use today. Each type can be altered to meet different end-use or fabrication requirements. Most types can be made available in several different forms. The result is a variety that can be confusing to the uninitiated. This manual takes you behind the meaningless array of tradenames, numbers and chemical labels. It tells you what types of structural adhesives are available, how their properties can be altered, in what forms they are available, for what bonding methods they are suitable, who makes them, and for what applications they are recommended. It also tells you how to go about selecting the right adhesive for a specific application.

MATERIALS & METHODS
MANUAL No. 110

This is another in a series of comprehensive articles on engineering materials and their processing. Each is complete in itself. These special sections provide the reader with useful data on characteristics of materials or fabricated parts and on their processing and applications.

NOVEMBER 1954

Table 1—Typical Characteristics o

Type	Available Form	Commercial Bonding Methods	Commonly Used Solvents	Usual Curing Time	Room Temperature Properties[a]			
					Creep Res	Shear Str	Peel Str	Imp Str
Polyvinyl Acetates	Liquid Emulsion Coated dried film	Solvent-release Water evaporation Reactivation	Ketones, toluol, methyl acetate Toluol, trichloroethylene Toluol, methyl ethyl ketone	At 250–350 F, 3 sec	P-F P-F P-F	G G G	F-M G G	P-G P-G P-G
Polyvinyl Alcohols	Liquid	Water evaporation	Water only		P-F	F	F	G
Acrylics	Liquid Liquid Liquid	Solvent-release Emulsions Catalyst	Esters, ketones	At R.T. 30 min-24 hr	P P F-G	F F F	P P G	G G G
Cellulose Nitrates	Liquid	Solvent-release	Acetates, ketones, alcohols		P-M	F-G	M-G	M-G
Asphalts	Liquid Liquid Solid	Solvent-release Water evaporation Heat	Naphtha Water		P-M P-M P-M	P-M P-M P-M	P P P	F F F
Oleoresins	Liquid	Solvent-release	Naphtha		P-F	M	P-G	F

NOTES:

P = poor, F = fair, M = moderate, G = good, and E = excellent.

[a] Properties vary somewhat with the materials to which the adhesive has be bonded, the bond thickness, etc.

[b] Depends also upon whether joint used is structural or non-structural.

Types of Adhesives

The number of adhesives marketed presently is very large and is constantly growing by new types or by compounding of existing types. Since many adhesives are marketed by trade names without identification of the chemical group to which they belong, their identification is often quite difficult and confusing to the user. Compounding of several groups of adhesives into new types, hardening the same types with different catalysts, or incorporation in the formulation of fillers, extenders and other modifiers further complicates their classification.

In fact, many of the major adhesives manufacturers disagreee with the approach of describing adhesives in accordance with the base materials used in their respective formulations. There is some justification in this since the engineer should be more concerned with the end properties and cost than with the particular adhesive formulation. It is not uncommon that an adhesive manufacturer has several customers bonding the same material with completely different adhesives. Of course, in most cases their end uses differ in regard to strength, heat resistance, joint thickness, chemical resistance and other requirements. To recommend that a particular basic adhesive type (for example, a phenolic) should be used for joining wood to metal may be very misleading. For these reasons most manufacturers of adhesives try to insist that questionnaires be carefully completed by the prospective user whenever there is a possible question regarding the exact nature of the bonding requirements. Sometimes samples of the items to be bonded are also requested. The great variation in service requirements is also the reason why many of the major adhesives manufactures have literally hundreds and hundreds of formulations, many of which have been specifically designed to do a certain job, in some cases for an individual user and in others for an entire industry.

Nevertheless, to bring some order into this apparent complete confusion, the materials engineer usually finds it necessary to approach his adhesive problems from the standpoint of the basic ingredients and properties of available adhesive formulations.

In structural-type and/or metal-bonding applications distinction is ordinarily made among four groups of adhesives:

1. Thermoplastic adhesives
2. Thermosetting adhesives
3. Elastomeric adhesives
4. Adhesive alloys

Basically adhesives are long chain-like molecules. They consist essentially of small molecules (called *monomers*) which are linked together as result of a chemical reaction called polymerization.

In thermoplastic and elastomeric adhesives the molecules occur in essentially long, linear chains with relatively little tying together (cross-linking) taking place. In the thermosetting adhesives, considerable tying together of the long-chain molecules occurs which results in a three-dimensional cross-linked molecular network. As a general rule, therefore, thermoplastic and elastomeric adhesives are more flexible though weaker than the thermosetting adhesives.

By changing or modifying the chemical composition or the size and shape of the molecules, extensive differences can be obtained in the properties of adhesives.

A monomer polymerized into a long-chain molecule generally is referred to as a *polymer*. Polymerization of the non-adhesive vinyl acetate into the adhesive polyvinyl acetate is an example. Polymerization of two different monomers may produce a copolymer with still different properties. An example is the synthetic Buna-N elastomeric adhesive produced by the polymerization of butadiene and acrylonitrile monomers.

Thermoplastic Adhesives

The thermoplastic adhesives (like waxes) can be softened or melted

Commercial Thermoplastic Adhesives

Service Temp, F		Resistance to:				Other Properties	Joint Design Preference[a]		Applications
Min	Max[b]	Water	Oil and Grease	Hydro-carbon	Solvents		Struc-tural	Non-Struc-tural	
−30	125	P-F	G-E	G-E	P-F	Wet tack-G	P	E	Metal glass, ceramics, mica, wood, cork, leather, cloths, paper and many plastics films
−30	125	P-F	G-E	G-E	P-F	Wet tack-G	P	E	
−30	125	P-F	G-E	G-E	P-F	Wet tack-G	P	E	
−30	150	F	E	E	G	Wet tack-E	P-F	G	Paper and film laminates (packaging)
	125	F-G	G	F-G	P	Clear bonds		G	Plastics
	125	F-G	G	F-G	P	Clear bonds		G	
	125	F-G	G	F-G	P			G	
		E	E	E				G	Metals, glass, wood, leather, cloths, thermo-plastic resins, etc.
0-30	100–200	E	P	P	P-F	Tack-G	P	E	Asphalt tile, concrete, glass, paper and felts
0-30	100–200	E	P	P	P-F	Tack-G	P	E	
0-30	100–300	E	P	P	P-F	Tack-G			
−20	100–150	F-G	F-G	P-F	P	Tack-E	G	G	Acoustical tile, masonite, linoleum, plasterboard, cork and similar materials

Structural Adhesives—A Long Way in 40 Years

Prior to World War I the only adhesives used in volume were vegetable and animal-base glues limited primarily to the bonding of porous materials such as wood, paper, textiles and leather products. For example, vegetable glue has been widely used in plywood manufacture since about 1903. Developments made during the First World War resulted in their first important aircraft application. Casein glues were used in structures on airplanes where it was recognized that high torsional rigidity was obtained by gluing the plywood skin to the wooden box spars. This allowed elimination of the external bracing of the wings necessary on the earlier planes.

Further advances came with the develoment of thermosetting urea-formaldehyde and phenol-formaldehyde synthetic adhesives during the 1920's and 30's which, unlike the vegetable and animal-base and casein glues, exhibited excellent resistance to water and to mold and fungus attack. Interest in further development of adhesives continued to be limited primarily to plywood and other wood products for furniture and housing, and to bookbinding and packaging. Interest in adhesives remained strong also in the aircraft industry where problems arose with the gradual substitution of light metal for wood, because urea and phenol-formaldehyde adhesives were limited to joints where at least one of the surfaces to be joined was porous. Thus metal-to-metal joints had to be made either by means of screws or rivets or by welding, brazing or soldering.

A real need existed for alternate methods to join metals not only to themselves and each other but also to other non-metallic materials. The need for better and more economical fabricating methods also led to a continued search for the improvement of existing methods by the adoption of new know-how gained in related fields. Rubber essentially was the first "plastic" of commercial importance. The developments of the various resin types resulted in their being processed, modified and evaluated also as adhesives. When found to offer useful adhesive properties they were marketed as commercial formulations.

The great bulk of adhesives is still being used in "non-structural" applications in the packaging and textile industries. Most common types of glues are the "flour-water" glues, the hide and bone glues, and the polyvinylacetates. Next in importance are the HCHO condensation glues for plywood, and the rubber-base adhesives.

Until the late 1940's the "structural-type" adhesives were primarily used in the aircraft and automotive industries. Since then more and more industries have begun to accept adhesives as reliable bonding materials for structural-type joints.

(often repeatedly) by heating, and hardened by lowering the temperature. The major characteristics of the more common types of thermoplastic adhesives are summarized in Table 1.

The ready softening or melting of thermoplastic adhesives is advantageous in that the bonded joint can be separated by slight indirect heating of the bonded area. It is disadvantageous in that the softening occurs at temperatures considerably below the melting point. At best, thermoplastics may be used at temperatures up to 150 to 200 F if the bond is essentially unstressed (i.e., a non-structural type of joint). Because of their relative softness, they exhibit poor creep strength even at room temperature—a weakness which must be compensated for by incorporating into the design, wherever possible, caps, folded overlaps or rivet stiffeners. Most of the lower molecular-weight thermoplastic adhesives become brittle at sub-zero temperatures.

Polyvinyl acetate adhesives provide good adhesion to metal, glass, wood, cork, leather, fabrics, paper and many plastics, and are extensively used in the paper container, shoe and furniture industries. They are also used for laminating metal foil and cellulose acetate film to paper. Most formulations are marketed as water emulsions with a solids content varying between 30 and 60%, which is

higher than the solids content of the corresponding solvent-release types. The cured adhesive is characterized by good toughness and water resistance.

Polyvinyl alcohol adhesives are used primarily on cellulosic materials as, for example, in packaging of foods. They are marketed as water emulsions. Starch or clay are widely used as extenders.

Acrylic adhesives are used to bond plastic materials, particularly thin products where transparency of the adhesive is desirable. Compounding may vary their properties from soft and tacky to tough and hard.

Cellulose nitrate adhesives are used to bond metals, glass, wood, leather, cloth, thermoplastic resins and other materials. They are also well known for their use as versatile household cements.

Asphalt adhesives are widely used in bonding of asphalt and plastic flooring tiles, concrete, glass, cork, paper and felts to each other and to metals. For example, they are employed extensively in fastening sound deadening and insulating felt to metal equipment. Their strength, even at room temperature, is relatively poor. Compounding, particularly with natural and reclaim rubbers, is widely employed to improve toughness, heat resistance, and other properties. They are generally marketed as emulsions or solvent-release formulations.

Oleoresin adhesives are primarily used in bonding plastic and metal wall (acoustical) tile, masonite, linoleum, plasterboard, cork and similar materials to each other and to metals. These adhesives exhibit good tack and wetting characteristics.

Thermosetting Adhesives

The thermosetting adhesives will soften with heat only long enough for the cure to start. Upon completion of the curing reaction they will remain essentially hardened, and cannot be remelted. They will, however, decompose upon exposure to temperatures exceeding certain limits characteristic of each particular material. The limit depends upon factors such as state of cure, and temperature and time of curing. Although most of the thermosetting adhesives will not decompose unless heated above 500 F, some may decompose even as low as 150 F.

The original strength developed by thermosetting adhesives may be higher than that of the thermoplastic and elastomeric types, although it will vary with the base materials bonded. Since thermosetting adhesives do not soften significantly at room and slight elevated temperatures, they are characterized by relatively good creep resistance. Thus, they are generally preferred in applications where the bond remains under stress. Nevertheless, with increasing temperature thermosetting adhesives will lose strength.

The major characteristics of the more common types of thermosetting adhesives are summarized in Table 2.

Phenolic adhesives provide excellent adherence to wood, metals, and glass. For bonding they usually require heat and pressure. Phenolic resins are also extensively used as modifiers blended with elastomeric and thermoplastic adhesives to improve their adhesion, strength, and heat or chemical resistance.

Resorcinol and *phenol-resorcinol* adhesives are marketed as liquid resins, usually in the form of alcohol-water solutions. Formaldehyde (pure or as mixture), supplied as a separate

Table 2—Typical Characteristics o

Type	Available Form	Commercial Bonding Methods	Commonly Used Solvents	Usual Curing Time	Room Temperature Properties[a]			
					Creep Res	Shear Str	Peel Str	Imp Str
Phenolic	Liquid	Heat (250–300 F) and pressure (150–300 psi)	Alcohol, acetone, water	5–10 min	G		F	F-M
	Powder	Heat (250–300 F) and pressure (150–300 psi)	Alcohol, acetone, water	5–10 min	G		F	F-M
	Films	Heat (250–300 F) and pressure (150–300 psi)	Alcohol, acetone, water	5–10 min	G		F	F-M
Resorcinal Phenol-resorcinal	Liquid	Cold Heat (75–250 F) and pressure (10–200 psi)	Water Water	8–24 hr 1 min–8 hr	G G	3000 3000		
Epoxy (ethoxyline)	Liquid	Catalyst	Acetone	16–76 hr	E	1000–3000	F	M
	Paste	Catalyst		12–48 hr	E	1000–3000	F	M
	Liquid	Heat (250–500 F)	Acetone	10 min–24 hr	E	2000–4000	F	M
	Paste	Heat (250–500 F)		10 min–24 hr	E	3000–5000	F	M
	Powder	Heat (250–500 F)		10 min–24 hr	E	3000–5000	F	M
	Rod	Heat (250–500 F)		10 min–24 hr	E	3000–5000	F	M
Urea-Formaldehyde	Liquid	Pressure (30–250 psi)		10 min–12 days	G		P	F
	Powder	Pressure (150–250 psi)		10 min–12 days	G		P	F
Melamine-Formaldehyde	Liquid	Pressure (25–50 psi)		5 min–12 days	G		P	F
	Powder	Pressure (150–250 psi)		5 min–12 days	G		F	F-M
Alkyds	Liquid	Contact pressure				M		G

NOTES:

P = poor, F = fair, M = moderate, G = good, and E = excellent.

[a] *Properties vary somewhat with the materials to which the adhesive has been bonded, the bond thickness, etc.*

[b] *Depends also upon whether joint used is structural or non-structural.*

component, is added to the resin solution prior to the bonding operation to start the hardening reaction. After mixing, the solution should be kept cool. Although good bonds may be obtained at room temperature (8-24 hr), heating to 200-250 F may reduce the curing times to as little as a few minutes. These adhesives are used primarily to bond plywood and other wood products, as well as cellulose acetate, nylon, acrylic and phenolic plastics.

Epoxy (ethoxyline) adhesives provide excellent adherence to metal, glass, ceramics, wood and most plastics. They have good wetting characteristics. They can be formulated to exhibit excellent capillary flow at temperatures between 250 and 350 F, so that upon application to the edge, they flow readily into the joint and are subsequently cured. Only contact pressure is required for good bonding.

Urea-formaldehyde adhesives are widely used for bonding plywood and other wood products. For bonding they usually require pressure between 150 and 250 psi. Heating is not always required. However, curing rates may be increased by heating at temperatures up to 260 F. Thus, commercial practice generally consists of hot-pressing at temperatures of 240 to 260 F. Modifiers such as furfural alcohol are added to many formulations to avoid crazing in thick "glue" lines and to improve strength. Extenders such as flour are sometimes added to reduce cost, although flour is not added to the craze-resistant types.

Melamine-formaldehyde adhesives are being increasingly used in the plywood and woodworking industries. For reasons of cost they are generally combined with urea resins. Curing at temperatures between 240 and 260 F at pressures between 150 and 250 psi is essential.

Alkyd adhesives are used primarily to bond metal laminations as used in motors and transformers. They are also used as sealers in plumbing fittings and in maintenance of washing machines and similar equipment. They generally do not contain solvents. Therefore bonded surfaces may be closed immediately upon application of the adhesive. Depending upon the catalyst, curing may be accomplished at room temperature or by slight heating at temperatures up to 200 F. Some formulations are modified by thermoplastic monomers and catalysts (styrene, acrylics, etc.) to extend or modify their properties.

Elastomeric Adhesives

Most of the elastomeric adhesives are considered similar to the thermoplastic resin adhesives in that they soften with increasing temperature, though generally at a slower rate. However, they never melt completely, but remain viscous and sticky until they decompose. The major characteristics of the more common types of elastomeric adhesives are given in Table 3.

In commercial practice almost all elastomers are modified with resins which may be thermoplastics (as rosin, ester vinyl gum, etc.), or thermosetting (as phenolic, epoxy, etc.). By further adding curatives to the thermoplastic formulations these elastomeric-base adhesives may be made thermosetting. The few straight elastomeric-base adhesives (no resins) available commercially usually are marketed as low-strength cements for bonding paper and other similar materials.

Bonding of the elastomeric-base ad-

Commercial Thermosetting Adhesives

Service Temp, F		Resistance to:				Other Properties	Joint Design Preference		Applications
Min	Max[b]	Water	Oil and Grease	Gasoline	Solvents		Structural	Non-Structural	
−30	212	E	E	E	E		G	E	Plywood and other wood products, metal and glass. Also extensively used as modifiers in elastomeric and thermoplastic adhesives.
−30	212	E	E	E	E		G	E	
−30	212	E	E	E	E		G	E	
−300	350	E	E	E	E	Resistant to boiling water	G	E	Plywood, certain plastics, marine and sports equipment.
−300	350	E	E	E	E		G	E	
−60	225	E	E	E	M-E	Wetting-G	E	E	Metal-to-metal products, and metal to glass, ceramic, many palstics, cyclized rubbers and wood.
−60	225	E	E	E	M-E	Wetting-M	E	E	
−60	375	E	E	E	G-E	Wetting-E	E	E	
−60	375	E	E	E	G-E	Wetting-E	E	E	
−60	375	E	E	E	G-E	Wetting-E	E	E	
−60	375	E	E	E	G-E	Wetting-E	E	E	
−30	120	G	E	E	E		G	E	Plywood and other wood products.
−30	120	G	E	E	E		G	E	
−30	120	G	E	E	E		G	E	
−30	212	E	E	E	E		G	E	
−60	200	E	E	E			F	E	Metal laminations and as sealers of plumbing fittings and in washing machines.

Table 3—Typical Characteristics of

Type	Available Form	Commercial Bonding Methods	Commonly Used Solvents	Usual Curing Time	Room Temperature Properties[a]			
					Creep Res	Shear Str	Peel Str	Imp Str
Natural Rubbers	Liquid	Solvent release	Hydrocarbons		P	P-F	P-M	M-E
	Liquid	Pressure (low)	Hydrocarbons		P	P-F	P-M	M-E
	Liquid	Vulcanization (cold)	Hydrocarbons	R.T.—24 hr	F	P-F	P-M	M-E
	Liquid	Vulcanization (hot)	Hydrocarbons	260–350 F—10–30 min	F	P-M	P-M	M-E
	Emulsion	Water evaporation	—		F	P-F	P	M-E
	Tape	Pressure (low)	Hydrocarbons		F	P-F	P	M-E
Reclaim Rubbers	Liquid	Solvent release	Hydrocarbons		P	P-F	P	M-E
	Liquid	Pressure (low)	Hydrocarbons		P	P-F	P	M-E
	Liquid	Vulcanization (cold)	Hydrocarbons		F	P-F	P	M-E
	Liquid	Vulcanization (hot)	Hydrocarbons		F	P-F	P	M-E
	Emulsion	Water evaporation	—		P	P-F	P	M-E
	Tape	Pressure (low)	Hydrocarbons		P	P-F	P	M-E
GR-S (Butadiene-styrene)	Liquid	Solvent release	Hydrocarbons		P-F	P-F	P	M-E
	Liquid	Pressure (low)	Hydrocarbons		P-F	P-F	P	M-E
	Liquid	Vulcanization (cold) or (hot)	Hydrocarbons		P-F	P-F	P	M-E
	Emulsion	Water evaporation	—		P-F	P-F	P	M-E
Neoprene	Liquid	Solvent release	Toluol, acetates		G	M-E	P-G	M-E
	Liquid	Vulcanization (cold) or (hot)	Acetates		G	M-E	P-G	M-E
	Emulsion	Water evaporation	—		G	M-E	P-G	M-E
Buna-N (Acrylonitrile-butadiene)	Liquid	Solvent release	Ethyl, acetate, acetone, methyl ethyl ketone		P-E	M-E	P-G	M-E
	Emulsion	Water evaporation	—		P-E	M-E	P-G	M-E
Silicone	Liquid	Heat (300–450 F) and pressure (low)		5–10 min	M-G	F-M	P-M	M-E
	Tape	Heat (300–450 F) and pressure (low)		5–10 min	M-G	F-M	P-M	M-E

NOTES:

P = poor, F = fair, M = moderate, G = good, and E = excellent.

[a] Properties vary somewhat with the materials to which the adhesive has been bonded, the bond thickness, etc.
[b] Depends also upon whether joint used is structural or non-structural.

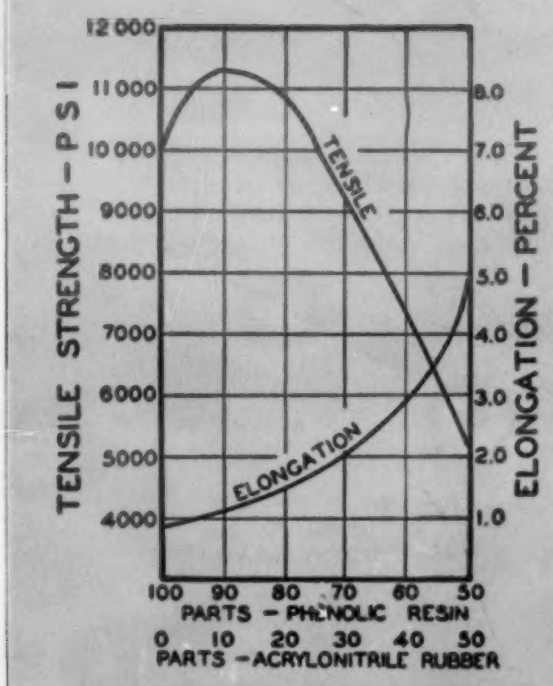


Fig 1—Strength and elongation of phenolic-acrylonitrile rubber blends. (B. F. Goodrich Co.)

hesives may be accomplished by solvent release, water evaporation or vulcanization.

The characteristics of each of these groups are varied considerably by compounding. For example, the Buna-N types can range from adhesives having high tackiness, high peel strength, but low shear strength to grades with poor tackiness but high peel and shear strengths. Compounding also may cause considerable variation in properties such as flexibility, elasticity and creep strength. As an illustration, the effects of blending phenolic resins with acrylonitrile rubber upon the tensile properties and elongation of the resulting resin alloy are given in Fig. 1.

Natural and *reclaim* rubber-base adhesives are used to bond tile, plasterboard, wood, felt, fabric, sponge rubber, paper, masonite, etc. to each other and to metals and to fasten metal attachments. They generally exhibit excellent tackiness and tack retention. Surfaces precoated with natural and reclaim rubber adhesives will bond satisfactorily when pressed together even weeks after application of the adhesive to both surfaces. As such they are also known as "self-seal" adhesives. These adhesives are also widely used as pressure-sensitive adhesives applied to one side of a fabric and usually marketed in the form of tapes.

The synthetic elastomers most widely used in adhesives are Buna-N (acrylonitrile-butadiene), Buna-S or GR-S (butadiene-styrene), neoprene, and polyisobutylene (butyl and vistorex). Properly compounded with thermoplastic or thermosetting resins these elastomeric materials are widely marketed as general purpose adhesives.

The *silicone* adhesives show considerable promise as "high"-temperature adhesives, retaining their strength and adherence at temperatures exceeding 300 F. They are one of several types of adhesives which bond to polyethylene, polytetrafluoroethylene (Teflon) and the silicone rubbers. Formulations are available which are

Commercial Elastomeric Adhesives

Service Temp, F		Tack	Tack Retention	Resistance to:				Joint Design Preference		Applications
Min	Max[b]			Water	Oil and Grease	Hydro-Carbon	Solvent	Struc-tural	Non-Struc-tural	
−70	150	E	E	E	P	P	P	P	E	Tile, glass, wood, and metal attachments, bristle setting.
−70	150	E	E	E	P	P	P	P	E	
−70	150	E	E	E	P-F	P	P-F	P	E	
−70	150–200	E	E	E	P-G	P-F	P-E	P	E	
−30	150	E	E	E	P	P	P	P	E	
+40	150	E	E	E	P	P	P	P	E	
−30	150	F-E	E	E	P	P	P	P	E	Rubbers, fabrics, felt, sponge rubber, flooring, etc. (Used as cheap extenders of natural rubbers).
−30	150	F-E	E	E	P	P	P	P	E	
−30	150	F-E	E	E	P-F	P	P-F	P	E	
−30	150	F-E	E	E	P-F	P	P-G	P	E	
−20	150	F-E	E	E	P	P	P	P	E	
−30	150	F-E	E	E	P	P	P	P	E	
		P-F	E	E	P	P	P	P	E	Fabrics, foils, pressure-sensitive tapes, plastics film laminates.
		P-F	E	E	P	P	P	P	E	
		P-F	E	E	P	P	P	P	E	
		P-F	E	E	P	P	P	P	E	
−40	180	P	F	E	E	G	P-M	P	E	General purpose, sponge rubber, plastics, table tops.
−40	180	P	F	E	E	G	P-M	P	E	
−40	180	P	F	E	E	G	P-M	P	E	
−60	200	P-G	G	E	E	E	F-M	P	E	General purpose, shoe sole cement.
−60	200	P-G	G	E	E	E	F-M	P	E	
−60	400							E	E	Heat resistant and pressure sensitive.
−60	400							E	E	

essentially thermoplastic while others exhibit thermosetting properties even when uncompounded.

Adhesive Alloys

Many commercial adhesives consist of several basic resin types compounded or blended together. The major characteristics of the more common types are summarized in Table 4.

Phenolic-polyvinyl acetal adhesive blends are used in metal-to-metal and wood-to-metal bonding. They show good strength, impact and fatigue properties. These include blends of reactive phenolics and polyvinyl formal, polyvinyl acetal and polyvinyl butyral.

Phenolic polyvinyl-butyral adhesive blends are used in the bonding of synthetic rubbers and plastics to metals, as well as in metal-to-metal and wood-to-metal (sandwich) bonding in aircraft construction. Because of good durability and electrical properties, they are also widely used in electrical applications as wire enamels.

Phenolic polyvinyl-formal adhesive blends are tougher than phenolic polyvinyl-butyral adhesives. They are extensively used in aircraft construction and in honeycomb sandwich skin bonding.

Phenolic-nylon adhesive blends are used in metal-to-metal and glass-to-metal bonding.

Phenolic-neoprene adhesive blends are used in the bonding of metals, wood and many plastics, usually in large structural applications. The adhesive blend exhibits good fatigue and impact strengths.

Phenolic-Buna-N adhesive blends are extensively employed in brake linings, structural aircraft, metal fabrication, grinding wheels and similar applications. They are characterized by good elevated temperature strength. Although for most formulations 300 F is considered the maximum temperature in continuous service, short intermittent exposures may be tolerated as high as 500 to 600 F.

Bonding Methods

From a practical point of view adhesives also may be classified by the method of bonding employed. As a broad classification the various bonding methods may be divided into those which effect curing of the adhesive at room temperature and those which require heat. The adhesives which may be cured at room temperature usually are referred to as *cold-setting*, whereas those requiring heat generally are labeled as *hot-setting*. The separation between these two groups is not always apparent since the curing rate of most cold-setting types may be increased by slight heating at temperatures up to 212 F. On the other hand, most hot-setting adhesives are not cured to a significant degree unless heated at temperatures above 212 F, so that 212 F usually is considered as a convenient separa-

Table 4—Typical Characteristics of Commercial

Type	Available Form	Commercial Bonding Methods	Commonly Used Solvents	Usual Curing Time, Min.	Room Temperature Properties[a]			
					Creep Res	Shear Str	Peel Str	Imp Str
Phenolic-Vinyl	Liquid	Heat (250–500 F) and pressure (50–500 psi)	Ketones, alcohol-toluol	5–45	F-G	E	G	G
	Tape	Heat and pressure		5–45	F-G	E	G	G
	Liquid + powder	Heat and pressure		5–45	F-G	E	G	G
Phenolic-Polyvinyl Butyral	Liquid	Heat (250–400 F) and pressure (50–300 psi)	Ketones, alcohol-toluol, acetate	5–45	F-G	G	G	M
	Tape	Heat and pressure		5–45	F-G	G	G	M
Phenolic-Polyvinyl Formal	Liquid	Heat (250–500 F) and pressure (50–500 psi)	Ketones, alcohol-toluol	5–45	F-G	G	G	M
	Tape	Heat and pressure		5–45	F-G	G	G	M
	Liquid + powder	Heat (250–500 F) and pressure (50–500 psi)		5–45	F-G	G	G	M
Phenolic-Nylon	Liquid	Heat and pressure	Alcohol	5–45				
Phenolic-Neoprene	Liquid	Heat (300–500 F) and pressure (50–500 psi)	Ketones	15–30	F-M			
	Tape	Heat		15–30	F-M			
Phenolic-Buna-N	Liquid + powder	Heat (300–500 F) and pressure (50–200 psi)	Ketones	15–30	G	E	E	G
	Tape	Heat (300–500 F) and pressure (50–200 psi)		15–30	G	E	E	G
	Liquid	Cold or wet \ with solv. react. / pressure			F-G	G	E	G

NOTES:

P = poor, F = fair, M = moderate, G = good, and E = excellent.

[a] Properties vary somewhat with the materials to which the adhesive has been bonded, the bond thickness, etc.

[b] Depends also upon whether joint used is structural or non-structural.

tion between the cold- and hot-setting types. [Provided, of course, that the "cold"-setting adhesive can be cured at room temperature. A few adhesives which can be cured only at low heat (between 100 and 212 F) are sometimes called intermediate-temperature settings.]

Most adhesives can be formulated into several basic types requiring different bonding methods. A convenient separation often made distinguishes the following types:

1. Solvent release
2. Emulsion
3. Vulcanization
4. Catalyst
5. Hot-setting (heat only)
6. Heat and pressure
7. Reactivation

The distinction among these classifications is not always readily apparent and there is some overlapping. Moreover, these types usually cannot be related to the basic resin in the adhesive. Whereas some basic adhesives are joined by only one of the above methods, in most others curing may be produced by several methods. For example, elastomeric adhesives are available in formulations which either require a separate catalyst for hardening, or harden by solvent release or water evaporation, without or with pressure.

A clear distinction is particularly difficult in commercial adhesives blends which possess varying combinations of thermoplastic and thermosetting properties. Many formulations may be 1) air dried and then bonded with heat, or 2) baked to increase their general resistance and then hot bonded, or 3) allowed to complete their cure gradually during elevated temperature exposure which tends to improve heat (creep) resistance.

In the proper selection of an adhesive, consideration of bonding characteristics, specific adhesion and bond strength, and method of bonding are important. For example, where the parts to be joined need to be positioned after contact, adhesives have to be used which do not result in a hardened joint too soon upon contact. The catalyst, hot-setting, pressure and heat, and pressure types generally allow sufficient time for positioning. On the other hand, many solvent release types will bond instantly upon contact of precoated and dried surfaces and cannot be moved. Available equipment, production requirements, material and production costs, end properties and service conditions are other factors that may govern the preference of one bonding method (or material) over another.

Solvent Release Types

As the name implies, curing is accomplished by the escape of solvents. (In asphalt-base adhesives the solvent vehicle types are known also as "cutback" types.) Because of the release of vapors, the use of most types is limited to applications where at least one of the two surfaces being bonded is porous. However, many solvent release types can be used to bond non-porous surfaces. In such cases the solvent is dried prior to the closing of the coated surfaces. Bonding is subsequently accomplished under pressure and/or heating.

By precoating sheet materials and drying out the solvent, these types are also made widely available as tapes and/or supported films. Wiping with cloth containing a suitable solvent or heating will give the adhesive tape proper bonding characteristics (also called reactivation).

In large scale production these adhesives are usually supplied in drums or large containers. They should be

Compounded or Blended Adhesive Alloys

Service Temp, F[b]		Resistance to:				Joint Design Preference		Applications
Min	Max	Water	Oil and Grease	Hydro-Carbon	Solvents	Structural	Non-Structural	
		E	E	E	G	E	E	Wood and metals to metals.
		E	E	E	G	E	E	
−70	240	E	E	E	G	E	E	
−60	200	E	E	E	G	G	E	Plastics and rubbers to metals.
−60	200	E	E	E	G	G	E	
−60	200	E	E	E	G	G	E	Wood and metals to metals, aircraft construction.
−60	200	E	E	E	G	G	E	
−60	200	E	E	E	G	G	E	
		M						Glass and metal to metals.
−60	150	E	E	E		G	E	Metals, wood and many plastics.
−60	150	E	E	E		G	E	
−60	300	E	E	E	G	E	E	Brake linings, oil filters, electrical assemblies, metal-to-metal joints.
−60	300	E	E	E	G	E	E	
−60	200	G	G	G	F	F	E	General purpose, industrial and household, metal-to-metal, glass, etc., bonding.

used under properly ventilated conditions. Excessive thickening of the adhesive during use may be avoided by addition of suitable solvents.

For small scale production, these adhesives are available in dispensing tubes or small bottles that need to be closed immediately after removal of the quantity of material required for the bonding operation.

The solvent content may vary over wide ranges, even though the basic resin may be the same. Thus, many thermoplastic and thermosetting adhesive types may be formulated to contain from less than 10% to over 50% of solvent. Elastomeric adhesives contain 50 to 95% solvents, usually over 80%.

Emulsion Types

These adhesives consist of stable dispersions of water-insoluble liquids or solids in water. They are known also as water vehicle types. Emulsifying agents are added to decrease the surface tension. Catalysts, solvents and modifiers such as fillers, plasticizers and thickeners may influence considerably the curing characteristics of an emulsion.

As was the case with the solvent release types, most formulations are used primarily in applications where at least one of the two surfaces being bonded is porous (i.e. wet-bonding). However, emulsion types of adhesives also are satisfactory for non-porous surfaces if the adhesive, upon application to both surfaces, is allowed to dry. Upon subsequent contact of the pre-dried surfaces heat and/or pressure are applied to complete the cure. Freezing usually damages the bonding properties of an emulsion.

When it is desirable to dilute further the emulsion, water may be added to the emulsion (not vice versa) accompanied by vigorous stirring. This should preferably be done immediately prior to the use of the emulsion.

Some emulsion-types of adhesives may contain also a small amount of solvents (5%) to increase tackiness and improve water resistance.

Some emulsion types require high pressures of the order of 50 to 500 psi to break the water emulsion and develop the best bond strength of the respective formulations. In commercial practice hydraulic presses developing pressures of 50 to 1200 psi are widely used. The desirable pressures vary with each particular formulation.

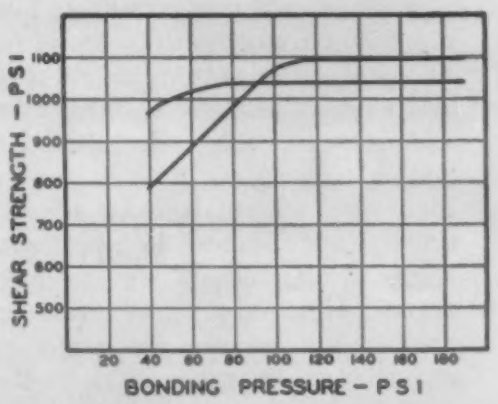


Fig 2—Bonding pressure vs shear strength of two adhesives. (G. S. Learmonth)

This is illustrated in Fig 2 where the maximum shear strength is developed in one adhesive with 80 psi pressure whereas another adhesive requires 120 psi pressure to develop its best strength properties.

Vulcanization Types

Curing is accomplished by a chemical reaction between the elastomeric adhesive and a so-called vulcanizing agent. Although sulfur is most commonly used as the vulcanizing agent, aromatic amines, peroxides or other chemicals are also used commercially. Catalysts are present in many formu-

lations to speed up the vulcanization reaction.

Vulcanization may be accomplished either cold or by heat. Where room temperature bonding is desired the adhesive and vulcanizing agent are supplied as separate components to be mixed together at time of use. Hot bonding formulations are marketed generally as premixed one-component products. In these materials bonding usually takes place upon heating to temperatures between 250 and 350 F.

Catalyst Types

Adhesive formulations requiring a catalyst for hardening at room or slightly elevated temperatures (i.e. below 212 F) are generally marketed as two separate components. The first, usually a liquid but sometimes a paste, contains the resin base to which solvents, fillers and/or other modifiers may have been added. The other liquid contains the catalyst (or hardener). In the case of pastes and high viscosity liquids, thinners may also have been added to the catalyst. These two liquids have to be mixed in the proportions recommended by the manufacturer immediately preceding actual use. Depending upon factors such as the resin formulation and the type of catalyst used, complete bonding may be accomplished in as little as a few minutes to as much as several days. Where solvents have been added to the resin formulation the rate of curing is usually reduced. Moreover, solvent bearing adhesives usually are limited to applications where at least one of the surfaces is porous. Heating at above room temperature will increase the rate of curing, though for many catalysts there is an upper temperature limit, usually between 150 and 250 F.

With many adhesives, some pressure is often necessary to obtain intimate contact and develop maximum bond strength. Actually pressure alone does not cause the cure, since curing is a chemical temperature-dependent reaction whose rate is practically independent of pressure. Some adhesives, such as urea-formaldehyde types, are available also as powders with the hardener incorporated. Upon mixing with water immediately prior to use the curing reaction is initiated.

Whereas many adhesives require only a little more than contact pressure, such as the epoxies, others may need pressures as high as 300 to 500 psi, e.g., the urea-formaldehyde types.

Hot-Setting (Heat Only) Types

The hot-setting types, as the name implies, require heat for curing. These materials are usually marketed as one-component products in that the catalyst (curing agent) has been mixed in with the resin. Depending upon the formulation, the curing reaction becomes significant only upon heating to temperatures above 200 to 300 F. Moreover, the rate of curing tends to increase with temperature. For example, minimum curing times of certain epoxy-base adhesives are as follows:

Temperature, F	Min Curing Time
250	24 hr
275	10 hr
300	5 hr
325	2 hr
350	1 hr
400	30 min
450	15 min
500	7 min

Changes in composition or compounding or addition of solvents or fillers may reduce or increase the required curing cycles.

Many hot-setting types are commonly marketed as liquid, paste, rod or powdered products. Most paste, rod or powdered forms soften upon heating and, upon reaching temperatures over 200 to 300 F, liquefy prior to the subsequent curing reaction. At the lower curing temperatures where curing rates tend to be fairly slow, the adhesive can be applied on preheated metal surfaces and remain free-flowing for periods sufficient to allow positioning of large sections and escape of air bubbles adhering to the metal surface or entrapped in surface cavities.

The hot-setting vulcanization types, already mentioned, more correctly should be included in this classification.

Some hot-setting adhesives are available also as pressure-sensitive tapes. Typical examples are the silicone elastomeric adhesives applied to both sides of cellophane tapes. Upon inserting the tape between the surfaces to be bonded and heating to 300 to 400 F the resulting shrinkage of the cellophane tape supplies sufficient pressure to provide good adhesion of the fully cured adhesive. Elastomeric and thermosetting adhesives both are marketed applied to cellophane tapes.

Heat and Pressure Types

In these types of adhesives, heat and pressure both are necessary to develop the maximum bond strength in the adhesive. With most adhesives pressures between 25 and 500 psi and temperatures between 225 and 450 F are required. The longer the holding time and the higher the temperatures and pressures, within the ranges recommended by the manufacturer, the greater usually is the bond strength. Typical data are given in Fig 3, illustrating the effects of pressing time on the room and elevated temperature shear strengths of aluminum alloy strips bonded with a phenolic-polyvinyl formal adhesive blend at 300 F and 100 psi. Whereas in this adhesive room temperature shear strength was little affected by curing time, the elevated temperature strength was considerably improved by the longer periods. Higher pressures and temperatures, however, may modify these relations.

Bond strength of some adhesives is improved by applying the adhesive cold to the surface and drying at 200 to 250 F to drive out the solvent prior to the final bonding, heating and pressing operation.

Several blended heat and pressure types (e.g., phenolic-Buna-N) are marketed as a liquid and powder two-component product. Prior to use the liquid and powder products are mixed and applied to the surfaces to be bonded. After air drying, the surfaces are brought into contact and the adhesive is cured under heat and pressure.

Reactivation Types

Many of the elastomeric and thermoplastic adhesive formulations containing solvents, after application to the surfaces to be bonded and drying, may be reactivated by wiping with a soft cloth containing an appropriate solvent. Some adhesives may also be reactivated by slight heating, usually to temperatures between 150 and 250 F. Heat reactivation is preferred

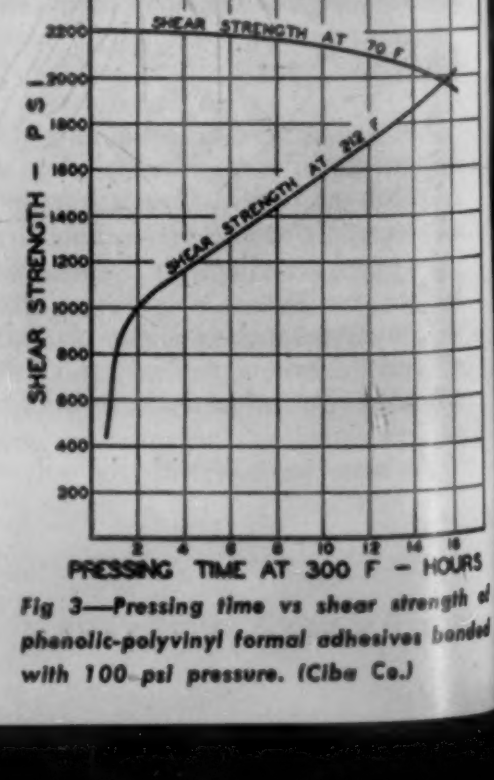


Fig 3—Pressing time vs shear strength of phenolic-polyvinyl formal adhesives bonded with 100 psi pressure. (Ciba Co.)

where non-porous surfaces are to be joined immediately and/or where maximum strength is desired.

Where thermoplastic adhesives applied to porous surfaces have been reactivated, the surfaces should be joined immediately.

Solvents and Modifying Agents

In the selection of adhesives containing solvents the formulation should be such that evaporation of solvent takes place at rates neither too slow nor too rapid for the intended application (see Table 7). Too slow a rate may result in entrapment of volatiles which may seriously reduce the bond strength of the adhesive. On the other hand, excessively rapid evaporation may "seal" the surface of the adhesive and prevent the passage of the volatiles from within.

Consideration of air drying (slow rates) vs oven drying (rapid rates) may have a serious bearing upon the quality of the joint.

The drying rates of various solvents are illustrated in Table 5. Since the drying time varies with the relative affinity of the respective adhesive, the rates are given as ratios comparing them to the drying rate of ethyl ether; i.e. toluol will require approximately five times the drying period as ethyl ether.

Solvents are also used to adjust the viscosity of adhesives to be suitable for spraying, immersion, brushing or other application methods. The effects of solvent content upon the viscosity of polyvinyl acetate adhesives are illustrated in Fig 4.

Besides resin, catalyst and solvent, various modifying agents are often added to the formulation to modify the properties of the adhesive or its bonding characteristics. Common modifiers are marketed or known as fillers, plasticizers, extenders, stabilizers, softeners, and wetting agents.

Fillers are considered as essentially non-adhesive materials added to the basic resin to produce desirable changes in the working and bonding characteristics, electric properties, strength, toughness, heat resistance, and other properties. Organic fillers such as wood flour, wheat flour or walnut-shell flour, and graphite and inorganic fillers such as asbestos, silica, metallic powders and glass fibers are widely used. The primary purpose of most metallic powders is to provide a good color-match with the materials to be bonded.

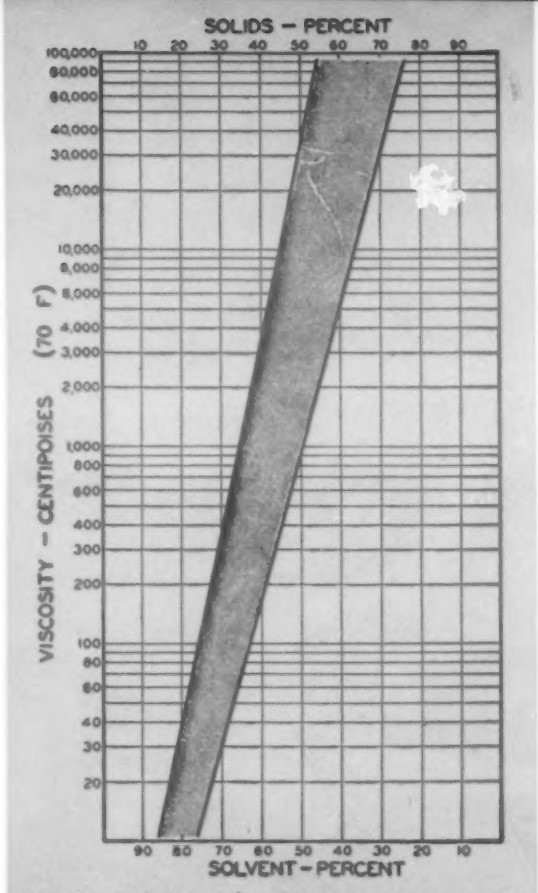


Fig 4—Relation of solvent content on viscosity of polyvinyl acetate adhesives.

Table 5—Approximate Rates of Drying of Commercial Solvents (Expressed as Ratio)

Solvent	Distillation range, F	Drying time ratio
Ethyl ether	—	1
Acetone	—	1.25
Methyl ethyl ketone	—	2.1
Methyl isobutyl ketone	—	6.0
Toluol	—	5.0
Xylol	—	9.7
Ethyl acetate	—	2.5
Butyl acetate	—	9.6
Ethyl alcohol	—	7.7
Butyl alcohol	—	4.8
Ethylene dichloride	—	3.0
Naphtha	150–160	1.5
Naphtha	145–205	1.8
Naphtha	120–278	2.6
Naphtha	203–262	3.6
Naphtha	242–290	7.2
Naphtha	217–302	7.7
Naphtha	306–408	55.0

Extenders are those low-cost substances which, when added to an adhesive, reduce the amount of primary binder required and, in this manner, lower the cost of the adhesive formulation. Typical extenders are starch, dextrin, clay, gelatin, etc.

Stabilizers are added to some commercial elastomeric adhesives (for example Buna-N) to improve their resistance to heat, light and/or chemical decomposition. Most commonly used are benzoic and lactic acid. Proprietary antioxidants (resins) are also sometimes used to increase heat resistance.

Softeners sometimes are incorporated to increase flexibility and/or provide tackiness. Oils are typical softeners. Plasticizers and high-boiling solvents also are occasionally used as softeners.

Wetting agents may be added to those adhesive formulations (or catalysts) where good wetting to the surfaces to be bonded is important, as in spray applications. Typical wetting agents, such as those added to polyvinyl acetate emulsion adhesives, are sulfonated alcohols and anionic or cationic agents.

Modifiers are also used as *inhibitors* to slow down the curing reaction, *thickeners* to increase the viscosity of the adhesive, antioxidants to provide increased resistance to heat and aging, *color pigments* to impart special colors and *inorganic pigments* to increase strength.

Some of these modifiers are suitable only for certain adhesive types whereas others may be added to many or all types.

Selecting the Right Adhesive

The selection of an adhesive type and formulation should take into consideration the following questions:

1. Does the adhesive adhere to the *base* materials which are to be bonded?

2. Does the adhesive meet the *service requirements* of temperature, stress and loading, and chemical environment?

3. Does the adhesive satisfy the *design and joint* requirements?

4. Can the adhesive be applied by

Table 6—General Commercial† Practice Followed in Adhesive

	Leather	Paper	Wood	Felt	Fabrics	Teflon Plastics
Metals	1, 4, 21, 24, 25	1, 21, 22	1, 4, 11, 13, 21, 31, 32, 33, 35, 36	1, 5, 22	1, 21, 22, 24	13*, 26
Glass, Ceramics, etc.	1, 4, 13, 24	1, 21, 22	1, 13, 21, 31, 32, 33, 35, 36	1, 5, 6, 21, 22	1, 21, 22, 24	13*, 26
Tile, etc.	1, 4, 21, 24	1, 21, 22	1, 5, 6, 21, 22	5, 6, 21, 22	5, 6, 21, 22, 24	—
Masonite	1, 21, 24	1, 21, 22	1, 5, 6, 21, 22	5, 6, 21, 22	5, 6, 21, 22, 24	—
Rubber	21, 24	21, 22	21, 22, 33, 35, 36	21, 22	21, 22, 23	—
Phenolic Plastics	21, 24, 25	21, 22	11,13,21,24,32,33,36	21, 22, 25, 36	21, 22, 24, 25	13*
Vinyl Plastics	21	21	21	21	21	—
Teflon Plastics	13*	13*	2*, 13*	2*, 13*	2*, 13*	—
Fabrics	21, 22, 23, 24	21, 22, 23	21, 22, 23	5, 21, 22, 23	1, 21, 22, 23	
Felt	21, 22, 23, 24	21, 22, 23	21, 22, 23	5, 22		
Wood	21, 22, 23, 24	2, 21, 22	1, 11, 12, 14, 15, 36			
Paper	21, 22, 23, 24	2, 4, 21				
Leather	1, 4, 21, 22, 23, 24					

† *Other adhesives also may be satisfactory.*
* *Special formulations.*

Table 7—Typical Commercial Conditions Influencing

TO MEET THESE REQUIREMENTS			. . . . . USE THESE	
Surface Characteristics	Production Requirements	Strength Requirements	Formulation	Form
2 non-porous surfaces	Immediately upon application of adhesive	Low	90–100% solids (fast drying or curing)	Liquid, film
			100% solids	Liquid, paste powder, rods, film
2 non-porous surfaces	Deferred (predrying possible)	Low	20–100% solids	Liquid
2 non-porous surfaces	Immediately upon application of adhesive	High*	90–100% solids (fast drying)	Liquid
			100% solids	Liquid, paste, powder or rods
2 non-porous surfaces	Deferred (predrying possible)	High	25–100% solids	Liquid
Non-porous and/or porous surfaces	Storage or handling without bonding or sticking together	Low	Rapid drying 30–80% solids	Liquid
Non-porous and/or porous surfaces	Large areas (predrying possible)	Low	30–70% solids, very slow drying and/or very slow curing	Liquid Liquid
		Low or high	70–100% solids	Liquid
Non-porous and/or porous surfaces (fillet-type joints)	Self curing upon application of adhesive	High	30–70% solids	Liquid
1 or 2 porous surfaces	Adhesive may penetrate into or bleed through porous surface	Low or high	70–100% solids	Liquid
1 or 2 porous surfaces	Adhesive must not penetrate into or bleed through porous material	Low	80–90% solids (high viscosity, fast drying)	Liquid or paste
			100% solids	Liquid or paste
1 porous surface	Application to metal surface with oil or grease film	Low	Special reclaim-rubber emulsion capable to absorb oil or grease	Liquid
2 porous surfaces	Immediately upon application of adhesive (very rapid cure)	Low or high	80–100% solids (fast drying or curing)	Liquid

* *Hot-setting adhesive types in powder or rod form may be sprinkled or rubbed over surfaces heated to temperatures between 200 and 500 F. Upon application they will melt and are flowed or spread over the surfaces to be joined.*

Selection for the Bonding of Similar and Dissimilar Materials

Vinyl Plastics	Phenolic Plastics	Rubber	Tile, etc.	Masonite	Glass, Ceramics, etc.	Metals
25, 36	3, 13, 21, 31, 32, 33, 35, 36	13, 21, 22, 31, 32, 33, 35, 36	5, 6, 13, 22, 35, 36	5, 6, 13, 22	13, 32, 33, 34, 35	11, 13, 31, 32, 33, 36
25, 36	3, 13, 21, 31, 35, 36	21, 22, 31, 35, 36	4, 22*	—	4, 13, 32, 35, 36	
25, 36	3, 13, 36	21, 22, 31, 35, 36	4, 5, 6, 22	5, 8, 13		
25, 36	3, 13, 36	21, 22, 31, 35, 36	5, 6, 22			
25, 36	21, 22, 36	21, 22, 31, 35, 36				
36	13, 32, 33, 36					
25, 36						

Thermoplastic	*Thermosetting*	*Elastomeric*	*Resin Blends*
1. Polyvinyl acetates	*11. Phenolics*	*21. Natural rubbers*	*31. Phenolic-vinyl*
2. Polyvinyl alcohols	*12. Resorcinol, phenol-resorcinol*	*22. Reclaim rubbers*	*32. Phenolic-polyvinyl butyral*
3. Acrylics	*13. Epoxies*	*23. GR-S*	*33. Phenolic-polyvinyl formal*
4. Cellulose nitrates	*14. Urea formaldehyde*	*24. Neoprene*	*34. Phenolic-nylon*
5. Asphalts	*15. Melamine formaldehyde, melamine urea*	*25. Buna-N*	*35. Phenolic-neoprene*
6. Oleoresins	*16. Alkyds*	*26. Silicones*	*36. Phenolic-Buna-N*

Selection of Adhesive Formulation and Basis of Bonding Adhesives

ADHESIVES

Bonding Type	Typical Application Method[a]	Examples
Catalyst, pressure (high), heat, heat and pressure	Brushing, roller coating, immersion	Shipping boxes
Catalyst, pressure, heat, heat and pressure	Brushing, immersion, spatula	Shipping boxes, knife handles
Heat, heat and pressure, catalyst, pressure (low or high)	Spraying, brushing, roller coating, flowing	Large flat surface, plastic to metal and wood laminates, oil filters
Pressure (high), heat, heat and pressure	Brushing, roller coating	Brake linings
Catalyst, heat, heat and pressure	Brushing, spatula	Brake linings, metal attachments
Heat, heat and pressure	Spraying, brushing, immersion	Motor laminations, honeycombs, printed circuits
Reactivation types by heat or solvent wiping	Spraying, roller coating, brushing	Precut weatherstrip, gaskets, vinyl coverings, phenolic plastic (Formica) tabletops
Solvent release, catalyst, emulsion	Spraying, brushing, roller coating	Metal sheets or plates to doors and walls, insulation to metal plates, etc.
Heat and heat pressure	Spraying, brushing, roller coating	Dissimilar metal sheets
Catalyst, heat	Spraying, immersion, gravity feed coating, flowing	Copper and aluminum fin tubing, radiators, etc.
Solvent release, catalyst, emulsion, heat, heat and pressure	Spraying, brushing, roller coating	Cork linings to metals, tile, etc.
Pressure (low)	Brushing, roller coating, spatula	Fabrics to porous or non-porous surfaces
Heat	Brushing, spatula	Fabrics to porous or non-porous surfaces
Pressure (low)	Spraying, brushing, roller coating	Felt pads to office and industrial equipment
Catalysts, pressure (low or high)	Brushing, spraying, roller coating, troweling	Most woods, wood to masonite, high pressure wood laminates

a practical *bonding method*? Has the bonding method an adverse effect upon one or both of the materials to be bonded?

5. Is the adhesive the most enonomical; i.e., has it a *cost* advantage?

6. Does the adhesive need to provide colors or a color match, exhibit dielectric strength, etc.?

Base Materials

The various types of adhesives ordinarily used to bond different materials are summarized in Table 6.

There are many applications where an adhesive type or certain special formulation cannot be bonded satisfactorily to the material listed in Table 6. On the other hand, satisfactory joints may be obtained with many combinations which differ from the general practice listed in Table 6. Obviously service conditions and joint designs have a major bearing upon material selection.

The effects of solvents and modifiers in the adhesive (or catalyst) formulations also need be considered. Some base materials may be softened by certain solvents in an adhesive formulation. When two different materials are to be bonded of which only one may be adversely affected by the solvents present in the adhesive, it may be possible to apply the adhesive to the surface not affected by the solvent, dry out the solvent, close the two surfaces and reactivate the adhesive by heating.

Possible chemical attack upon the base material may eliminate an adhesive formulation from consideration, particularly where the reactive products reduce adherence, bond strength, chemical resistance or the properties needed.

Service Requirements

In the selection of one or several suitable adhesive types, the service requirements also need careful consideration. Service properties of the more common adhesive types are given in Tables 1 to 4.

The effects of temperature are closely related to joint design and loading. As a general rule, in load-carrying applications the thermoplastic adhesives should not be used at temperatures exceeding 100 to 150 F, although properly compounded thermoplastic rubber-resin adhesive alloys may be satisfactory up to 200 to 250 F. Where the joint is non-structural or is reinforced by rivets or caps, somewhat higher temperatures may be tolerated. Similar considerations hold true for the elastomeric adhesives.

The thermosetting adhesives may be exposed to considerably higher temperatures. The maximum temperatures listed in Tables 3 and 4 are based on structural type joints exposed continuously to those temperatures. Higher temperatures are permissible for joint designs which minimize the stresses across the adhesive bond. Occasional peak temperatures as high as 500 to 600 F can be tolerated by most of these adhesives. For example, in brake linings bonds made with the phenolic-Buna-N adhesive will stand up satisfactorily to the maximum 600 F frictional heating occasionally experienced. Solvents, catalysts, fillers, plasticizers and other modifiers may reduce or increase significantly the elevated temperature properties of an adhesive.

Considerable differences exist in the mechanical properties of various types of adhesives and their many commercial modifications. Typical strength properties of the major adhesive types are given in Tables 1 to 4. The mechanical properties required of an adhesive are closely related to joint design. Where unfavorable service loads of the peelback and cleavage type might result in failure, redesign of the joint to change the stress conditions to tensile or shear types may allow the loads to be satisfactorily carried by the same adhesive. Hot-setting formulations often develop better strength properties and rigidity than cold-setting formulations of adhesives containing the same basic resins. On the other hand, most cold-setting formulations tend to produce bonds that are tougher and more flexible than their corresponding hot-setting formulations.

Resistance to environmental attack by water, solvents, acid solutions, and atmospheric conditions also must be considered. A number of adhesives may deteriorate in sun or ultraviolet light. Others may be attacked by bacteria, mold, or rodents, or be affected adversely by moisture or atmospheric conditions.

Design and Joint Requirements

Design and joint requirements, as mentioned already, also should be considered in the selection of the proper adhesive materials. Where structural type joints have to be used in which the adhesive bond is subjected to loads of considerable magnitude the thermosetting adhesives listed in Tables 2 and 4 are generally preferred. On the other hand, for non-structural types of joints the thermoplastic and elastomeric adhesives listed in Tables 1 and 3, respectively, may be most practical.

Illustrations of structural-type joint designs commonly used are shown in Fig 5.

As a general rule, it is good design practice to keep to a minimum the stresses across the adhesive. Joints should be designed to keep the adhesive in shear and avoid cleavage and peel stresses. Where the design is such that cleavage or peel stresses cannot be avoided, the bond should be strengthened by rivets, caps, overlaps, or rigid stiffeners. In fact, by means of these techniques, the non-structural adhesive types may be adopted for many bonding applications otherwise restricted to the structural adhesive types.

Joint properties are also a function of the thickness of the adhesive film. Ordinarily, shear and creep strength are highest for thin films of the order

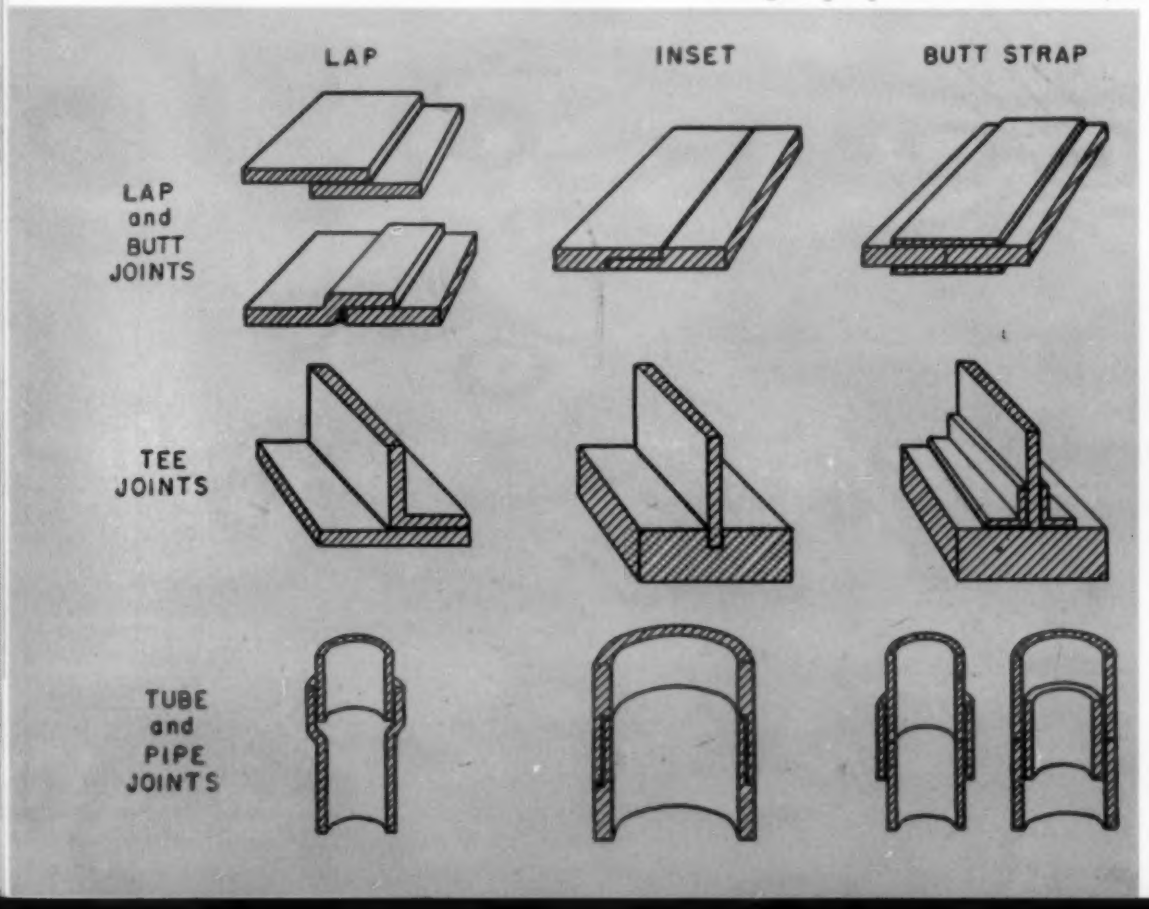


Fig 5—Typical joint designs.

of 0.001 to 0.003 in. On the other hand, heavier films may exhibit higher flexibility, toughness and better peel and cleavage strengths. Excessively thin (*starved*) joints are also undesirable in that they are likely to result in poor bond strength.

Bonding Method

The bonding method is closely related to the production requirements and equipment available. An adhesive formulation (i.e., solvent release type, catalyst type, hot-setting type, etc.) should be selected which is most practical and economical for the particular bonding operation. Typical conditions are summarized in Table 7.

The bonding method of the particular formulation also must be given careful consideration. Base materials which are softened by heat might not be bonded satisfactorily by adhesive formulations requiring heat and pressure.

Cost

After the four previously discussed factors have been taken into consideration, and certain types of adhesives seem satisfactory for the particular application, the cost involved in bonding the product must be carefully analyzed. A thorough study includes a) cost of adhesive materials including catalysts, solvents, fillers, etc., b) amount of adhesive required, c) cost of equipment, d) cost of application including labor, inspection, etc., e) method of bonding, f) space and handling requirements.

It must be realized that the cost of an adhesive cannot be evaluated on the price per pound basis alone. Thus, Table 8 in which the basic material prices of the major types of adhesives are summarized should be used only as a very approximate guide.

Table 8—Price Ranges of Commercial Types of Adhesives Based on 100% Solids Content

	Price per lb in 1000-lb lots
THERMOPLASTIC	
Polyvinyl Acetates	0.25–0.75
Polyvinyl Alcohols	0.20–0.60
Acrylics	0.50–1.20
Cellulose Nitrates	0.60–1.40
Asphalts	0.15–0.30
Oleoresins	0.25–0.45
THERMOSETTING	
Phenolics	0.20–0.85
Resorcinol, Phenol-resorcinol	0.45–0.85
Epoxies	0.75–5.00
Urea Formaldehyde	0.15–0.40
Melamine Formaldehyde	0.20–0.40
Melamine Urea	0.30–0.50
Alkyds	0.25–0.75
ELASTOMERIC	
Natural Rubbers	0.25–0.75
Reclaim Rubbers	0.15–0.60
GR-S	0.30–0.80
Neoprene	0.40–0.95
Buna-N	0.60–1.50
Silicones	—
RESIN BLENDS	
Phenolic-vinyl	—
Phenolic-polyvinyl-butyral	1.00–4.00
Phenolic-polyvinyl-formal	1.00–3.00
Phenolic-nylon	—
Phenolic-neoprene	1.00–2.50
Phenolic-Buna-N	1.20–3.50

Table 9—Sources of Commercial Adhesives

Type	Manufacturer	Location	Product Trade Name
THERMOPLASTIC			
Polyvinyl acetates	Arabol Mfg. Co.	New York, N. Y.	—
	Cordo Chemical Corp.	Norwalk, Conn.	Cordo-bond
	Federal Adhesives Corp.	Brooklyn, N. Y.	Fedco
	H. B. Fuller Co.	St. Paul, Minn.	—
	B. F. Goodrich Co.	Akron, Ohio	Plastilock
	National Adhesives	New York, N. Y.	National
	Paisley Products, Inc.	New York and Chicago	—
	Polymer Industries, Inc.	Springdale, Conn.	Polybond
	Rubber & Asbestos Corp.	Bloomfield, N. J.	Bondmaster
	Swift & Co.	Chicago, Ill.	—
Polyvinyl alcohols	Arabol Mfg. Co.	New York, N. Y.	—
	Federal Adhesives Corp.	Brooklyn, N. Y.	Fedco
	H. B. Fuller Co.	St. Paul, Minn.	—
	National Adhesives	New York, N. Y.	—
	Paisley Products, Inc.	New York and Chicago	—
	Polymer Industries, Inc.	Springdale, Conn.	Polybond
	Swift & Co.	Chicago, Ill.	—
Acrylics	Federal Adhesives Corp.	Brooklyn, N. Y.	Fedco
	Rubber & Asbestos Corp.	Bloomfield, N. J.	Bondmaster
Cellulose nitrates	Miracle Adhesives Corp.	New York, N. Y.	Miracle
	National Adhesives	New York, N. Y.	National
Asphalts	Armstrong Cork Co.	Lancaster, Pa.	Armstrong
	Flintkote Co.	New York, N. Y.	Flintkote
	Ohio Adhesive Corp.	New Philadelphia, Ohio	Ohio Adhesives
	Rubber & Asbestos Corp.	Bloomfield, N. J.	Bondmaster
Oleoresins	Armstrong Cork Co.	Lancaster, Pa.	Armstrong
	Flintkote Co.	New York, N. Y.	Atlas
	Rubber & Asbestos Corp.	Bloomfield, N. J.	Bondmaster
THERMOSETTING			
Phenolic	Borden Co.	New York, N. Y.	Resinox
	Rubber & Asbestos Corp.	Bloomfield, N. J.	Bondmaster
Epoxy	Armstrong Products Co.	Warsaw, Ind.	Armstrong Adh.
	Bakelite Co.	New York, N. Y.	—
	Borden Co.	New York, N. Y.	Casophen
	Chrysler Corp.	Trenton, Mich.	Cycleweld
	Ciba Co.	New York, N. Y.	Araldite
	B. F. Goodrich Co.	Akron, Ohio	Plastilock
	Houghton Laboratories, Inc.	Olean, N. Y.	Hysol
	Miracle Adhesives Corp.	New York, N. Y.	Adweld
	Ohio Adhesive Corp.	New Philadelphia, Ohio	—
	Polymer Industries	Springdale, Conn.	Chemotec
	Shell Chemical Co.	New York, N. Y.	Epon
	Rubber & Asbestos Corp.	Bloomfield, N. J.	Bondmaster
Urea-formaldehyde	American Cyanamid Co.	New York, N. Y.	Urac
	Borden Co.	New York, N. Y.	Casco Resin & others
Alkyds	General Electric Co.	Pittsfield, Mass.	—
Melamine-formaldehyde	American Cyanamid Co.	New York, N. Y.	Melmac
Melamine-urea-formaldehyde	American Cyanamid Co.	New York, N. Y.	Melurac
Resorcinol and Phenol-resorcinol	Borden Co.	New York, N. Y.	Cascophen
ELASTOMERIC			
Natural Rubbers	Armstrong Cork Co.	Lancaster, Pa.	Armstrong
	Federal Latex Corp.	Brooklyn, N. Y.	Fedco
	Flintkote Co.	New York, N. Y.	Flintkote
	B. F. Goodrich Co.	Akron, Ohio	Goodrich
	National Adhesives	New York, N. Y.	National
	Polymer Industries, Inc.	Springdale, Conn.	—
	Rubber & Asbestos Corp.	Bloomfield, N. J.	Bondmaster
Reclaim Rubbers	Armstrong Cork Co.	Lancaster, Pa.	Armstrong
	Chrysler Corp.	Trenton, Mich.	—
	Flintkote Co.	New York, N. Y.	Flintkote
	B. F. Goodrich Co.	Akron, Ohio	Plastilock
	Miracle Adhesives Corp.	New York, N. Y.	—
	National Adhesives	New York, N. Y.	National
	Ohio Adhesive Corp.	New Philadelphia, Ohio	—
	Rubber & Asbestos Corp.	Bloomfield, N. J.	Bondmaster
GR-S	Chrysler Corp.	Trenton, Mich.	—
	Federal Latex Corp.	Brooklyn, N. Y.	Fedco
	Flintkote Co.	New York, N. Y.	Flintkote
	B. F. Goodrich Co.	Akron, Ohio	Goodrich
	Miracle Adhesives Corp.	New York, N. Y.	—
	National Adhesives	New York, N. Y.	National
	Ohio Adhesive Corp.	New Philadelphia, Ohio	—
	Polymer Industries, Inc.	Springdale, Conn.	Polybond
	Rubber & Asbestos Corp.	Bloomfield, N. J.	Bondmaster

(Table continued on page 128)

Table 9—Sources of Commercial Adhesives (continued)

Type	Manufacturer	Location	Product Trade Name
ELASTOMERIC (cont.)			
Neoprene	Borden Co.	New York, N. Y.	Casco Flexible Cement
	Chrysler Corp.	Trenton, Mich.	—
	Federal Latex Corp.	Brooklyn, N. Y.	Fedco
	Flintkote Co.	New York, N. Y.	Flintkote
	B. F. Goodrich Co.	Akron, Ohio	Goodrich
	Miracle Adhesives Corp.	New York, N. Y.	—
	Ohio Adhesive Corp.	New Philadelphia, Ohio	—
	Polymer Industries, Inc.	Springdale, Conn.	Polybond
	Rubber & Asbestos Corp.	Bloomfield, N. J.	Bondmaster
Buna-N	Chrysler Corp.	Trenton, Mich.	—
	Flintkote Co.	New York, N. Y.	Flintkote
	B. F. Goodrich Co.	Akron, Ohio	Goodrich
	Miracle Adhesives Corp.	New York, N. Y.	—
	Ohio Adhesive Corp.	New Philadelphia, Ohio	—
	Rubber & Asbestos Corp.	Bloomfield, N. J.	Bondmaster
	National Adhesives	New York, N. Y.	National
Silicones	Dow Corning Corp.	Midland, Mich.	—
	Flexrock Co.	Philadelphia, Pa.	Flexrock
ADHESIVE ALLOYS			
Phenolic-vinyl	Chrysler Corp.	Trenton, Mich.	Cycleweld
	B. F. Goodrich Co.	Akron, Ohio	Plastilock
	National Adhesives	New York, N. Y.	National
Phenolic-polyvinyl butyral	Bloomingdale Rubber Co.	Chester, Pa.	—
	Chrysler Corp.	Trenton, Mich.	Cycleweld
	Rubber & Asbestos Corp.	Bloomfield, N. J.	Bondmaster
Phenolic-polyvinyl formal	Ciba Co.	New York, N. Y.	Redux
	Rubber & Asbestos Corp.	Bloomfield, N. J.	Bondmaster
Phenolic-nylon	Chrysler Corp.	Trenton, Mich.	Cycleweld C-6
Phenolic-neoprene	Chrysler Corp.	Trenton, Mich.	Cycleweld
	B. F. Goodrich Co.	Akron, Ohio	Goodrich
	National Adhesives	New York, N. Y.	National
	Polymer Industries, Inc.	Springdale, Conn.	Polybond
	Rubber & Asbestos Corp.	Bloomfield, N. J.	Bondmaster
Phenolic-neoprene-nylon	Narmco Resins & Coating Co.	Costa Mesa, Cal.	Metlbond
Phenolic-Buna-N	Armstrong Cork Co.	Lancaster, Pa.	Armstrong N-199
	Bloomingdale Rubber Co.	Chester, Pa.	—
	Bond Adhesives Co.	Brooklyn, N. Y.	Tweezle
	Chrysler Corp.	Trenton, Mich.	Cycleweld H-2
	B. F. Goodrich Co.	Akron, Ohio	Plastilock
	Goodyear Tire & Rubber Co.	Akron, Ohio	Pliobond
	Minnesota Mining & Mfg. Co.	Saint Paul, Minn.	EC 1245
	National Adhesives	New York, N. Y.	National
	Rubber & Asbestos Corp.	Bloomfield, N. J.	Bondmaster

1. Where an adhesive formulation contains a large percentage of solvents or fillers, two, three or more times the total quantity may be required than where an adhesive is used which contains little or no solvents or fillers. This holds true among the major types of adhesives and within each particular type of which various formulations are available. In some instances dilution or concentration is used as a means of controlling film thickness.

2. Some adhesives develop their best properties when applied in thicker layers than others. Wetability and capillary flow properties may have a bearing upon the amount of adhesive required. The effects of solvent and filler content have been mentioned.

3. The equipment requirements represent another important consideration. In large production runs where heavy presses, ovens, autoclaves, etc. are feasible, the use of hot-setting adhesives may be most practical, since they generally require less time for curing and often develop better physical properties than the cold-setting types. On the other hand, in many applications, the cold-setting types may be completely satisfactory because they may require less equipment. Since slight heating (up to 212 F) reduces the curing rates of most cold-setting adhesives, the use of steel tables heated by hot water or steam piping, heating lamps or other arrangements may add further advantage to the use of the cold-setting adhesive types.

4. Labor cost is not proportional to the curing time required. The shorter-curing hot-setting adhesives may necessitate more labor time than corresponding cold-setting formulations. Thus, a cold-setting type may require labor for application and clamping after which the bonded and clamped assembly is set aside for curing without involving additional manpower. A corresponding hot-setting adhesive may require more labor time because of the necessity of properly controlling the furnaces. Solvent-bearing hot-setting adhesives which require cold application and drying prior to closing the surfaces and heat-curing may further increase labor cost. Set up time, inspection, etc. are other factors to be considered. In cases where elastomeric adhesives are used in bonding a rubber product, hot curing or vulcanizing adhesives are desirable in that they develop optimum bond strength at the curing temperature of the whole assembly.

5. The method of bonding also may have a bearing upon cost, primarily as it relates to labor and material costs. Thus, spraying may be less costly than brushing or roller coating, particularly in the production of large sections. Moreover, sprayed adhesive films, when uniformly applied, may allow satisfactory bonding with a thinner layer of adhesive than brushed adhesive films. On the other hand, adhesive formulations for spraying usually contain a higher solvent content than those applied by brushing or roller coating. The cost of the additional solvent required, although small, may enter into calculations. The higher-solvent content sprayed film also may take more time to dry than the lower-solvent content brushed film, unless a solvent is used that evaporates more rapidly.

6. Space and handling requirements, already mentioned, may increase costs and, as a result, influence material selection.

Miscellaneous Requirements

Other factors entering into material selection may be color requirements. Some adhesives are naturally opaque and cannot be produced in many colors, particularly when transparency is an additional requirement. Dielectric strength also may be a consideration. Other applications may require an adhesive exhibiting electrical conductivity. In many adhesives satisfactory conductivity (small) may be obtained with carbon or metal fillers.

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Flintkote Co.
B. F. Goodrich Co.
Goodyear Tire & Rubber Co., Inc.
Minnesota Mining and Manufacturing Co.
Miracle Adhesives Corp.
National Adhesives Corp. (National Starch Products, Inc.)
Paisley Products, Inc.
Polymer Industries, Inc.
Rubber and Asbestos Corp.

For more information, Circle No. 491

Materials Engineering File Facts

MATERIALS & METHODS
November • 1954
Number 288

Specifications for Laminated Plastics

Grade Description	NEMA Grade	Military Spec.	Military Spec. Type	JAN-P-13 Type LTS	Navy 17-P-5 Type	Army 71-484 Type	ASTM (D-709) Type	33 P-46 (AER) Bureau of Aeronautics	Federal Spec. L-L-31 (Formerly HHP-256)		AAF Spec. 12032
									Type	Grade	
SHEET											
Paper Filler—Hard Phenolic Resin	—	—	—	M-1	PBM	I	I	—	I	X	—
	X	MIL-P-6885 (Formerly AN-P-68)	I Cross Laminated II Parallel Laminated	M-2	PBM-1	I	I	—	I	X	—
Paper Filler—Plasticized Phenolic Resin	P	—	—	E-1	PBP	—	I-1	—	I	P	—
Paper Filler—Hard Phenolic Resin	XX	MIL-P-3115	PBG	E-2	PBG	I	I	—	I	XX	—
Paper Filler—Plasticized Phenolic Resin—For Hot Punching	XXP	—	—	E-3	—	—	I-2	—	I	XXP	—
Paper Filler—Hard Phenolic Resin	XXX	MIL-P-3115	PBE	E-4	PBE	I	I-4	—	I	XXX	—
Paper Filler—Plasticized Phenolic Resin—For Hot Punching	XXXP	MIL-P-3115	PBE-P	E-5	PBE-P	—	I-3	—	I	XXXP	—
Medium Weight Cotton Fabric Filler—Hard Phenolic Resin	C	MIL-P-15035	FBM	M-4	FBM	II	II	—	II	C	—
	CE	MIL-P-15035	FBG	EM-1	FBG	II	II-5	—	II	CE	—
Medium Weight Cotton Fabric Filler—Hard Phenolic Resin With Graphite Inclusion	—	—	—	—	—	—	—	CG	—	—	CG
Fine Weave Cotton Fabric Filler—Hard Phenolic Resin	L	MIL-P-15035	FBI	M-3	FBI	II	II	—	II	L	—
	LE	MIL-P-15035	FBE	EM-2	FBE	II	II-5	—	II	LE	—
Fine Weave Cotton Fabric Filler—Hard Phenolic Resin With Graphite Inclusion	—	—	—	—	—	—	—	LG	—	—	LG
Asbestos Paper Filler—Hard Phenolic Resin	A	MIL-P-8059 (USAF)	A	H-1	PBH	—	III	—	III	A	—
Asbestos Paper Filler—Melamine Resin	—	—	—	A-1	AMG	—	—	—	—	—	—
Asbestos Fabric Filler—Hard Phenolic Resin	AA	MIL-P-8059 (USAF)	AA	MH-1	FBH	—	III	—	III	AA	—
Staple Fibre Glass Cloth Filler—Melamine Resin	—	—	—	M-5	GBM GBH	—	IV	—	IV	—	—
Continuous Filament Glass Cloth Filler—Melamine Resin	G-5	MIL-P-15037	GMG	MG-1	GMG	—	IV	—	IV	G-5	—
Continuous Filament Glass Cloth Filler—Silicone Resin	G-7	MIL-P-997	GSG	—	GSG	—	IV	—	IV	G-7	—
Glass Mat Filler—Melamine Resin	G-8	MIL-P-17721 (SHIPS)	GMM	—	—	—	IV	—	—	—	—
Nylon Fabric Filler—Phenolic Resin	N-1	MIL-P-15047	NPG	—	—	—	V	—	V	N-1	—
Chopped Medium Weight Cotton Fabric—Hard Phenolic Resin	—	MIL-P-14	CFI-20	—	—	III	—	—	III	—	—

(Continued on page 133)

Specifications for Laminated Plastics (cont'd.)

Grade Description	NEMA Grade	Military Spec.	Military Spec. Type	JAN-P-79 Type LTS	Navy 17-P-5 Type	ASTM D-709 Type	33 P-46 (AER) Bureau of Aeronautics	Federal Spec. L-L-31	AAF Spec. 12032
ROLLED TUBING—FORM Tr									
Paper Filler—Hard Phenolic Resin	X	MIL-P-79	PBM	M-1	PBM	I	—	X	—
	XX	MIL-P-79	PBG	E-2	PBG	—	—	XX	—
	—	—	—	E-4	PBE	—	—	—	—
Medium Weight Cotton Fabric Filler—Hard Phenolic Resin	C	MIL-P-79	FBM	M-4	FBM	II	—	C	—
	—	—	—	EM-1	FBG	—	—	—	—
Fine Weave Cotton Fabric Filler—Hard Phenolic Resin	—	—	—	M-3	FBI	—	—	—	—
	LE	MIL-P-79	FBE	EM-2	FBE	II	—	LE	—
Asbestos Paper Filler—Hard Phenolic Resin	A	MIL-P-8059(USAF)	A	—	—	—	—	—	—
Asbestos Fabric Filler—Hard Phenolic Resin	AA	MIL-P-8059(USAF)	AA	—	—	—	—	—	—
Continuous Filament Glass Fabric Filler—Phenolic Resin	G-3	—	—	—	—	IV	—	G-3	—
Continuous Filament Glass Fabric Filler—Melamine Resin	G-5	MIL-P-79	GMG	MG-1	GMG	IV	—	G-5	—
MOLDED TUBING—FORM Tm									
Paper Filler—Hard Phenolic Resin	—	—	—	M-1	PBM	—	—	—	—
	XX	MIL-P-79	PBG	E-2	PBG	I	—	XX	—
	XXX	MIL-P-79	PBE	E-4	PBE	I	—	XXX	—
Medium Weight Cotton Fabric Filler—Hard Phenolic Resin	—	—	—	M-4	FBM	—	—	—	—
	CE	MIL-P-79	FBG	EM-1	FBG	II	—	CE	—
Medium Weight Cotton Fabric Filler—Phenolic Resin Graphite Inclusion	—	—	—	—	—	—	CG	—	CG
Fine Weave Cotton Fabric Filler—Hard Phenolic Resin	L	—	—	M-3	FBI	II	—	L	—
	LE	MIL-P-79	FBE	EM-2	FBE	II	—	LE	—
Fine Weave Cotton Fabric Filler—Phenolic Resin Graphite Inclusion	—	—	—	—	—	—	LG	—	LG
Asbestos Paper Filler—Hard Phenolic Resin	A	MIL-P-8059(USAF)	A	—	—	—	—	—	—
Asbestos Fabric Filler—Hard Phenolic Resin	AA	MIL-P-8059(USAF)	AA	—	—	—	—	—	—
Continuous Filament Glass Fabric Filler—Phenolic Resin	—	—	—	—	—	—	—	—	—
Continuous Filament Glass Fabric Filler—Melamine Resin	—	—	—	MG-1	GMG	—	—	—	—
MOLDED RODS—FORM R									
Paper Filler—Hard Phenolic Resin	—	—	—	M-1	PBM	—	—	—	—
	XX	MIL-P-79	PBG	E-2	PBG	I	—	XX	—
	XXX	MIL-P-79	PBE	E-4	PBE	I	—	XXX	—
Medium Weight Cotton Fabric Filler—Hard Phenolic Resin	C	—	—	M-4	FBM	II	—	C	—
	CE	MIL-P-79	FBG	EM-1	FBG	II	—	CE	—
Medium Weight Cotton Fabric Filler—Phenolic Resin Graphite Inclusion	—	—	—	—	—	—	CG	—	CG
Fine Weave Cotton Fabric Filler—Hard Phenolic Resin	L	—	—	M-3	FBI	II	—	L	—
	LE	MIL-P-79	FBE	EM-2	FBE	II	—	LE	—
Fine Weave Cotton Fabric Filler—Phenolic Resin Graphite Inclusion	—	—	—	—	—	—	LG	—	LG
Asbestos Paper Filler—Hard Phenolic Resin	—	—	—	H-1	PBH	—	—	—	—
Asbestos Fabric Filler—Hard Phenolic Resin	—	—	—	MH-1	FBH	—	—	—	—
Continuous Filament Glass Fabric Filler—Melamine Resin	G-5	MIL-P-79	GMG	MG-1	GMG	IV	—	G-5	—

(Courtesy of Synthane Corporation)

Tunnel within a tunnel — 8500-ft. exhaust ducts along the top of each Holland Tunnel tube are supported in the center by 7-ft. lengths of 2½-inch by ⅜-inch hot-rolled Monel flats. These hangers are installed every 8 feet.

The Holland Tunnel that drivers never see

How it's supported by corrosion-resisting Monel hangers

Drivers never see *this* tunnel because it is hidden above the ceiling of the Holland Tunnel.

This tunnel-within-a-tunnel provides a unique air exhaust system that completely changes the air in the Tunnel every minute and a half. Since the Holland Tunnel was opened in 1927, it has proved so successful that designers of the Lincoln Tunnel and other large tunnels have followed the same design.

In working out this unique exhaust system, Port of New York Authority engineers faced the problem of providing support for the tunnel ceiling (the exhaust duct floor). In order to minimize wind resistance, center support members or hanger rods from the cast iron tunnel shell to the ceiling had to be as thin as possible.

Monel flats provided the answer. The high strength of Monel and its corrosion resistance enabled the engineers to use hangers of minimum cross-section without requiring any allowance for corrosion.

A recent check showed these Monel hangers to be in as good condition as when installed. *No corrosion after 27 years, despite dampness and the continuously high concentration of corrosive engine fumes in the exhausted air.*

When *you* have a design problem involving corrosion and other destructive conditions, one of the Inco Nickel Alloys like Monel usually permits you to insure long service and, at the same time, to limit weight and bulkiness.

Inco has a concise booklet on the widespread applications of Inco Nickel Alloys. It's titled *Standard Alloys for Special Problems.* An exceptionally handy booklet for designers, it gives an overall picture of casting, joining, forms available and properties. It also refers to more detailed literature available on each subject. And it's yours for the asking, so why not write for it today.

The INTERNATIONAL NICKEL COMPANY, Inc.
67 Wall Street — New York 5, N. Y.

INCO TRADE MARK **Nickel Alloys**

MONEL® • "R"® MONEL • "K"® MONEL • "KR"® MONEL
"S"® MONEL • INCONEL® • INCONEL "X"®
INCONEL "W"® • INCOLOY® • NIMONIC® Alloys
NICKEL • LOW CARBON NICKEL • DURANICKEL®

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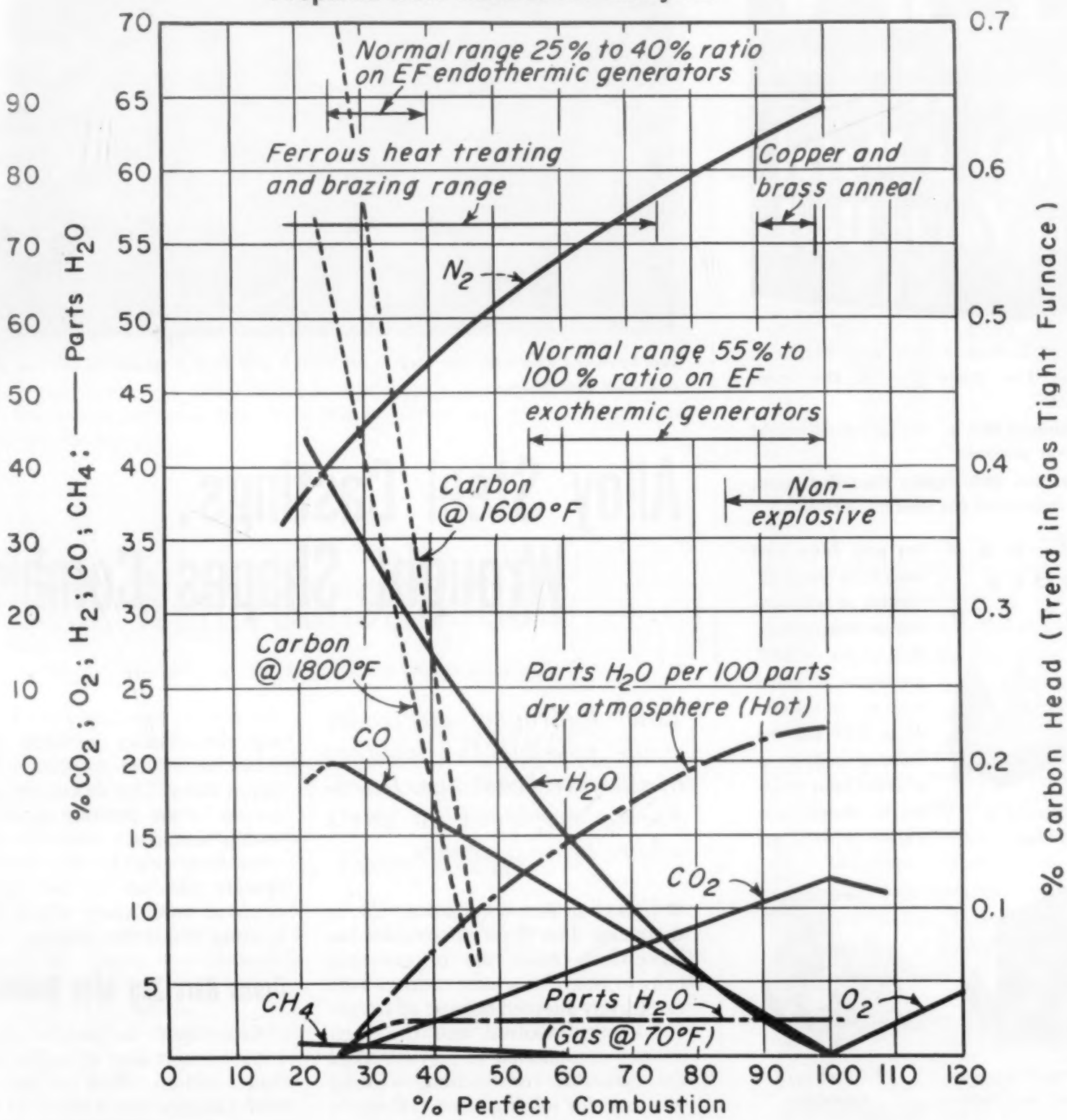
Materials Engineering File Facts

MATERIALS & METHODS
November • 1954
Number 289

Special Atmosphere Graph for Heat Treatment Prepared from Natural Gas Analyses*



B.t.u. Gas	Ratios					
530	0.94	1.88	2.82	3.76	4.7	5.64
1030	2	4.1	6.2	8.2	10.3	12.4
2550	4.8	9.6	14.4	19.2	24	28.8

*Curves for City Gas and Propane will be similar.

Above percentages on gas atmosphere constituents have been averaged from many complete analyses. Actual gas analyses compared with above curves will vary slightly due to differences in generator temperature, catalyst, completeness of reaction, raw gas analysis and air-fuel ratio.

Carbon head determinations are obtained by running .001 in. x 2-in. x 2-in. carbon steel specimens, of high and low carbon, through a gas tight furnace. After exposure to gas atmosphere in furnace or until equilibrium is reached the specimens are analyzed for carbon. About eight specimens are required for one chemical analysis.

Courtesy of the Electric Furnace Co.

Low hydrogen electrodes are used to arc weld a cast steel extension to one end of a large cast steel shoe beam.

Alloy Steel Castings, Wrought Shapes Combined

Low hydrogen electrodes make possible the welding of alloy steel castings. Hard-facing employed on parts where wear is severe.

● GENERAL RAILWAY SIGNAL CO. in designing their latest car retarder has successfully made use of cast-weld construction. Alloy steel castings were extensively adopted because of irregular shapes involved and the high stresses encountered in service. And for favorable construction, welding was used for joining some castings to each other and to wrought steel components. The result of this combination is a structure that is not only economical to build but favorable from a service and maintenance standpoint as well.

The car retarder is employed to decelerate railway freight cars. This is accomplished with shoes that bear against side faces of car wheels. Pressure of the shoes is exerted by heavy coil springs below cross bars, and the degree of pressure is varied to obtain the desired retarding force by adjusting the distance between opposed shoes before the car wheels pass between them. The shorter the gap, the greater is the pressure applied. Retarders commonly have six to eight cross bars, and the shoe beams they operate are set by an electrically operated mechanism which is in a housing beside the retarder.

Cross Bars and Shoe Beams

Cross bars themselves are SAE 1335 wrought steel of square rounded corner section. Each bar has several steel castings arc welded to it with 1/4-in. electrode. Most of the welds are fillet type, but at some points, especially in corners, the fillets are quite large.

The shoe beams are made of No. 57 alloy cast steel, containing 0.35 to 0.45 carbon, 1.30 to 1.60 manganese and 0.35 to 0.40% molybdenum. A cast steel end extension of the same alloy is welded to the shoe beam using 1/4-in. electrodes. Shoe beams are large and heavily stressed castings, and are used to support shoes at both

Applying a hard steel wear resistant surface to the tongue of a shoe beam casting by arc welding. This welded hardfacing comes inside and on bearing faces of the articulate joints of mating shoe beams.

in Cast-Weld Construction

by R. E. HAAS, District Engineer, the Lincoln Electric Co.

sides of each rail. These castings are placed end to end in rows that extend the full length of the retarder.

One end of each beam has a U-shape recess into which a tongue on the adjacent beam projects to form a sort of articulated joint. Beams at the ends of each row, however, each take an extension that is welded to one end of the beam. There is considerable space between the two parts, and it is filled with the weld metal.

By making the extension castings as separate pieces, all shoe beams are identical and molds for casting the beams are made from a single pattern. It is a simple matter to join the extension by welding. If it were cast integrally, two extra and expensive patterns would be needed, as the extensions at opposite ends of each row are not quite identical.

As both shoe beams and the extensions thereto are subjected to heavy shocks and stresses, the welded joints have to be strong. To assure satisfactory joints, low hydrogen electrodes were used for these and all other welds. They avoid the tendency to under-bead cracking, and allow the preheat and postheat treatment to be substantially reduced. Actually, the joints produce weldments that are as strong as one piece castings.

Bearing and Crank

A bearing and a crank shown in an accompanying illustration are cast respectively from No. 43 and No. 58 high carbon alloy steels. Each of these castings receives pack hardened SAE 1118 wrought steel bushings that are pressed in place and welded with a 5/32-in. electrode with alignment held very closely.

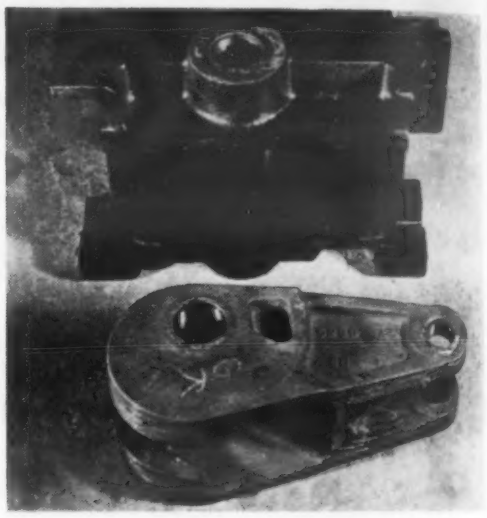
Bushings are hardened to 60 Rc and are ground before being pressed into holes machined to fit prior to welding. There is a slight chamfer on the outside diameter, and a slight relief on the inside diameter, at the ends of each bushing so that insertion is simplified and welding does not affect bearing fit. Holes in which the bushings fit are chamfered at their outer ends to provide a bevel in which the weld bead is laid down. Welding is done with a copper plug in the

(Continued on page 138)

Cast-Weld Construction

continued from page 137

Close-up of steel castings welded to crossbars. Many of fillet welds are visible.



Cast steel crank and bearing containing hardened wrought steel bushings pressed in place and fastened by circumferential arc welds laid down in bevels at ends of holes in castings.

bushing hole to avoid any weld spatter in the bore and to conduct away welding heat so that the hardness of the bore is not affected.

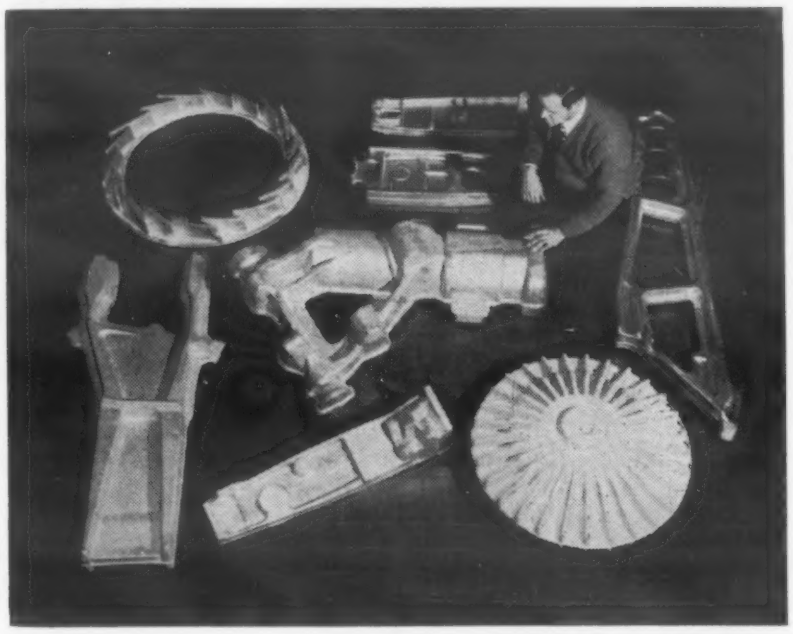
To minimize wear at the U-shape articulated joints between the ends of cast steel shoe beams, a hardfacing deposit is made with a semi-austenitic type electrode. This hardfacing deposit is about 1/8 in. thick, but there is sufficient clearance between the mating parts so that the thickness is not critical and no machining is required, although a check is made to be sure that clearance will be adequate to avoid binding when assembly is made.

Clearly, welding is used to good purpose and with advantage on several scores in this car retarder. Its excellent performance is an indication that welds provide adequate strength and the use of hard surfaces applied by welding certainly helps to reduce wear at joints where repair might otherwise be needed more frequently.

New Materials, Parts and Finishes

. . . and Related Equipment

Not a monster, but a huge manipulator placing forging stock on Alcoa's 15,000-metric ton forging press.



Typical aluminum forgings produced by Alcoa for aircraft and jet engine manufacturers.

New Aluminum Forging Alloy Gives

• Higher Strengths in Thick Sections

• Improved Ductility in Cross-Grained Directions

A new high strength forging alloy has been developed which provides higher and more uniform properties in thick sections (over 3 in.) and greater ductility in cross-grained directions. Designated X7079, the aluminum alloy is said to be less quench-sensitive than alloy 7075 (75S), thus providing more uniform properties in heavy sections. Limited tests also indicate that forgings of the new alloy may be less susceptible to distortion when machined. The alloy is the latest development of the *Aluminum Co. of America,* 1501 Alcoa Bldg., Pittsburgh 19, and is expected to be particularly advantageous in the large forgings to be produced under the Air Force Heavy Press Program.

At present, X7079, one of the zinc-magnesium-copper series of aluminum alloys, is being limited to forging applications. According to the company, attention is also being directed toward its possible use in other wrought products such as heavy plate and extruded sections.

Properties of Heat-Treated Alloy

The characteristics of the alloy have allowed the company to establish guaranteed mechanical properties in die and hand forgings in section thicknesses up to 7 in. in the T6 condition (solution heat treated and artificially aged). Following are the values as determined by test data for X7079-T6 in section thicknesses up to 7 in. (49 sq in.) heat treated in full section:

Hand Forgings

	Guaranteed Min	Typical
LONGITUDINAL		
Ten. Str., 1000 psi	73	77
Yld. Str., 1000 psi	62	67
Elong., % in 4D	9.0	13.0
LONG TRANSVERSE		
Ten. Str., 1000 psi	70	73
Yld. Str., 1000 psi	60	63
Elong., % in 4D	6.0	9.0
SHORT TRANSVERSE		
Ten. Str., 1000 psi	65	71
Yld. Str., 1000 psi	54	59
Elong., % in 4D	4.0	6.0

(Continued on page 142)

(Continued from page 141)

Die Forgings

	Guaranteed Minimum	Typical
PARALLEL TO FLOW LINES		
Ten. Str., 1000 psi	74	78
Yld. Str., 1000 psi	64	68
Elong., % in 4D	10.0	14.0
NOT PARALLEL		
Ten. Str., 1000 psi	72	76
Yld. Str., 1000 psi	61	66
Elong., % in 4D	4.0	9.0

According to the company, limited tests on hand forgings up to 12 in. in thickness, heat treated in full section, indicate tensile and yield strengths approximately 4-7000 psi lower than those shown for 7-in.-thick sections. For hand forgings over 7 in. thick the company will negotiate guaranteed minimum properties for particular sizes.

Other properties of 7079-T6 alloy:

Weight, lb/cu in. 0.099

Electrical Conductivity, % I.A.C.A. 31

Thermal Conductivity, C.G.S. Units at 25C 0.29

Fatigue Strength

Tests indicate fatigue strengths similar to 7075-T6 (75S-T6) for both smooth and notched specimens, in longitudinal and transverse directions.

According to the company, limited testing has shown that the new alloy is at least equal and probably superior to 7075-T6 from the standpoint of stress-corrosion cracking. Since service failures due to stress corrosion have not been encountered, the company expects no difficulty from this factor.

The machinability of X7079-T6 is expected to be the same as for 7075-T6, though tests indicate that it is somewhat less susceptible to distortion during machining than 7075-T6 and 2014-T6 (14S-T6).

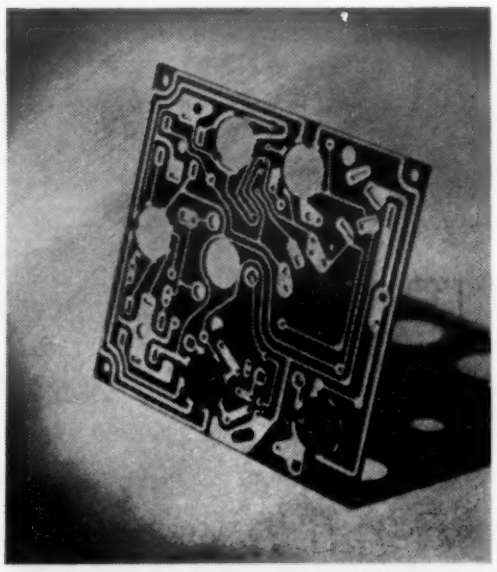
At present there are no government or customer specifications for the new alloy though steps are being taken to request inclusion in Federal Specification QQ-A-367c.

These miscellaneous parts were fabricated from new high temperature nylon molding powder.

Nylon Molding Powder Has High Distortion Point

A new nylon molding powder for injection molding is said to have a heat distortion temperature of 250 F when tested on a 1-in. dia bar at 264 psi. Developed by the *Polymer Corp.*, Reading, Pa. The material, called Nylatron GS, is a polyamide composition based on DuPont's Zytel 101 nylon and molybdenum disulphide.

The material is said to have a low coefficient of friction and excellent wear characteristics when used on dry bearings or wear surfaces. According to the producers, where dimensional stability of molded nylon parts is critical, the new formulation offers a coefficient of thermal expansion lower than that of the unfilled formulation.



This printed circuit is made on new laminate by Methode Mfg. Co.

Bond in Printed Circuit Laminate Improves with Age and Heat

A copper-clad printed circuit laminate incorporating a bond which is electrically equal to the laminate and improves with age and heat has been developed by *Mica Insulator Co.*, Schenectady, N. Y. Called Mico Cu-Clad Laminoid, the laminate is said to possess high bond strength, electrical performance, solderability, punchability, to be capable of withstanding 450-460 F without blistering and 300 F continuously for ½ hr without deteriorating. The bonding technique is also said to facilitate bonding copper to many Class A and Class B laminates.

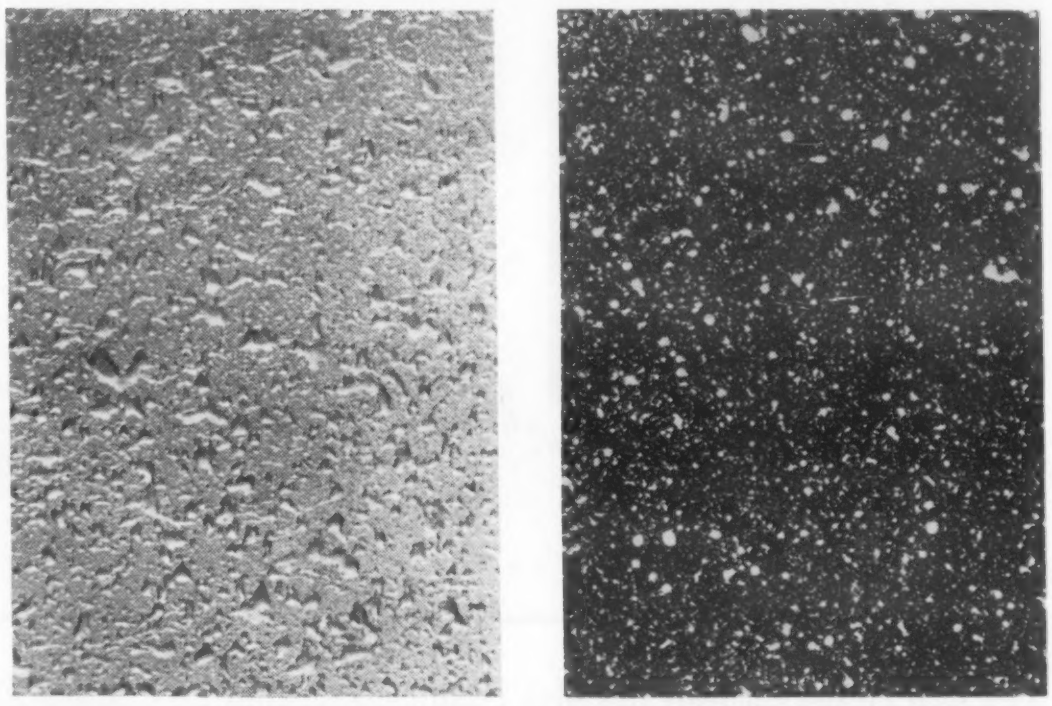
Tests on production lots of CuClad XXXP-grade laminates have indicated the following properties:

Bond Strength, guaranteed min, lb	6
avg, lb	9
Solder Test, guaranteed no blisters at 450-460 F, sec	10
Heat Resistance, guaranteed no change at 300 F (air-circulated oven, air flow parallel to specimen), hr	½
Punchability	Excellent
Surface Resistivity, megohms, C-96/35/90	7.3×10^4
Volume Resistivity, megohms, C-96/35/90	3.7×10^5
Water Absorption, copper on 1/16 in., D_1-24/23, %	0.1
Copper removed, %	0.7

Two New Decorative Finishes for Plastics

Two new coatings have been marketed to provide color and finishing effects on plastics. Logo Stipple X-88 is a stipple coating designed to form a textured base for application of colored finish coatings; Logo Spatter R-69 is available in a variety of colors and produces a spatter effect which may be backed with a continuous coating of another color to provide a two-color finish.

Produced by *Logo, Inc.*, 13799 South Ave. "O", Chicago 33, Logo Stipple may be used on plastics such as butyrate, acetate, acrylic, phenolic, polyester and polystyrene, while Logo Spatter is suitable for use on acrylic, polystyrene, Royalite and other types of finishes. It may be used on the first surface of opaque or the second surface of transparent plastic sheet. For second surface application, it may be backed by any contrasting color for the desired effect. For the first surface application, the continuous finish is applied first, and the spatter applied over it.



Polystyrene panel (left) has been coated with the Stipple and a gold topcoat. The finish on the transparent plastic panel (right), viewed through the panel, is made up of a coat of White Spatter and backed with Black. Any color combination may be used.

Silicone Polymer Adds Wide Temperature Range to Organic Rubber

A new silicone polymer, Dow Corning 410 Gum, that can be vulcanized with sulfur and either blended with or applied as a surface coat to organic rubbers to extend their temperature range to —70 to 400 F has been developed by *Dow Corning Corp.*, Midland, Mich. According to the producers, the physical properties of the resultant blends fill the gap between those of high strength silicone rubber and the organic rubber constituent. The polymer can also be blended with oil resistant rubbers to increase their stability in contact with hot oil and resistance to ozone and weathering.

Dow Corning 410 Gum

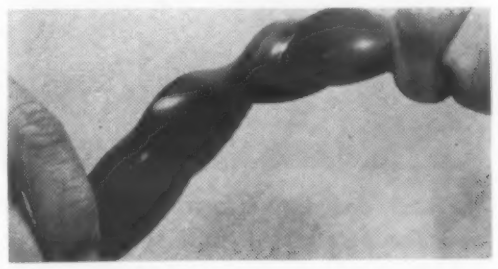
Clear and colorless, the gum is a high viscosity, high molecular weight, silicone polymer. According to the producer, it can be compounded and vulcanized by methods recognized as standard procedure in fabricating organic rubbers. Typical properties of 410 Gum are:

Plasticity (Williams), mils	45
Specific Gravity	0.98
Brittle Point (when vulcanized), F	-80

The Gum can be compounded with most of the fillers commonly used in organic rubber, and with conventional sulfur vulcanizing agents. Although not as heat-stable as the regular Silastic stocks which require an after-cure, parts vulcanized from the compounded gum are serviceable from —70 to 400 F with good resistance to oxidation and weathering.

Properties of a rubber compounded of 100 parts Dow Corning 410 Gum, 40 parts HiSil 303, 3 parts Methyl Tuads and 0.5 parts Captax indicate the physical characteristics obtainable. The following typical properties were obtained after 20 min vulcanization at 320 F:

Durometer, Shore A	63
Tensile Strength, psi-	850
Elongation, %	325
Brittle Point, F	-80

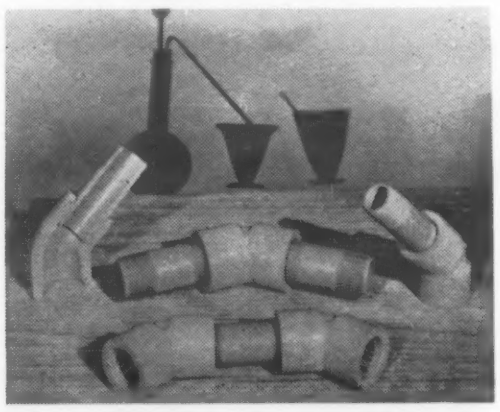


Tensile strength of bond between butyl (black) and new gum is equal to that of silicone component.

Compounded gum can also be vulcanized in contact with organic rubbers to yield a silicone coating having a high degree of resistance to weathering, heat and ozone. A better bond is attained between the organic and silicone components if they are separated by a blend of the two. Combined with high temperature organic rubbers, Dow Corning 410 Gum lowers their brittle point; increases their high temperature resistance. Combined with low temperature organic elastomers, it improves their high temperature serviceability and their low temperature characteristics.

New Materials, Parts and Finishes continued

Plastic Pipe Has High Toughness, Corrosion Resistance



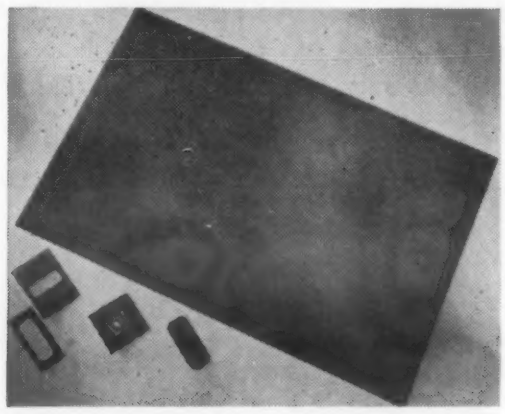
Some of the fittings available for the new corrosion resistant plastic pipe.

A new corrosion-resistant, rigid plastic pipe with a high degree of impact resistance and toughness has been marketed by the *American Hard Rubber Co.*, 93 Worth St., New York 13. It is a general purpose material designed for handling most common corrosive media.

Called Dur-Ace, the pipe is light weight, odorless, tasteless, and non-contaminating. According to the producers, the pipe has a high degree of resistance to all inorganic acids and alkalis with the exception of some strong acids and organic solvents. Moisture absorption is low and properties are said to be maintained over a temperature range of —40 to 170 F.

Working pressures at 70 F for the extra-heavy-wall pipe range from 300 psi for ½ in. to 150 psi for 2-in. diameters. For standard-wall pipe, working pressures range from 150 psi for ½ in. to 75 psi for the 2 in. At 170 F, working pressures are approximately half those recommended for 70 F operations. These pressures are based on a safety factor of 5 to 1. The pipe is easily threaded with standard pipe-threading tools, and it can be bent in regular pipe forming equipment if it is first softened by heat.

Low Cost Plastic Laminate Has High Electrical Properties



A sheet and typical parts stamped from new laminate.

A glass fiber-polyester laminate priced in the range of NEMA XX laminates is claimed to have higher heat stability, better impact strength, higher arc resistance and lower moisture absorption than XX laminates. Produced by the *Glastic Corp.*, 1823 E. 40th St., Cleveland 3, Ohio, Grade TS Glastic is said to couple these properties with punch - toughness. This latter characteristic allows holes to be punched close to the edge of the sheet and narrow strips to be sheared off without preheating, in thickness up to ½ in.

The material is said to be well suited for use in mounting panels, terminal strips, barriers, coil washers, bus supports, base plates and other insulating or supporting parts in switch gears, transformers, motors, controls and appliances. The material is available in thicknesses of 1/16 to ½ in. in sheets 24 x 36 in. and 36 x 72 in., and on request in thicknesses through 1-½ in.

Two New Compounds Aid Rust Elimination

Two new compounds have been developed to aid in derusting iron and steel. One is a non-electrolytic alkaline derusting compound which is said to leave the base steel clean and bright; the other converts rust into an iron phosphate coating.

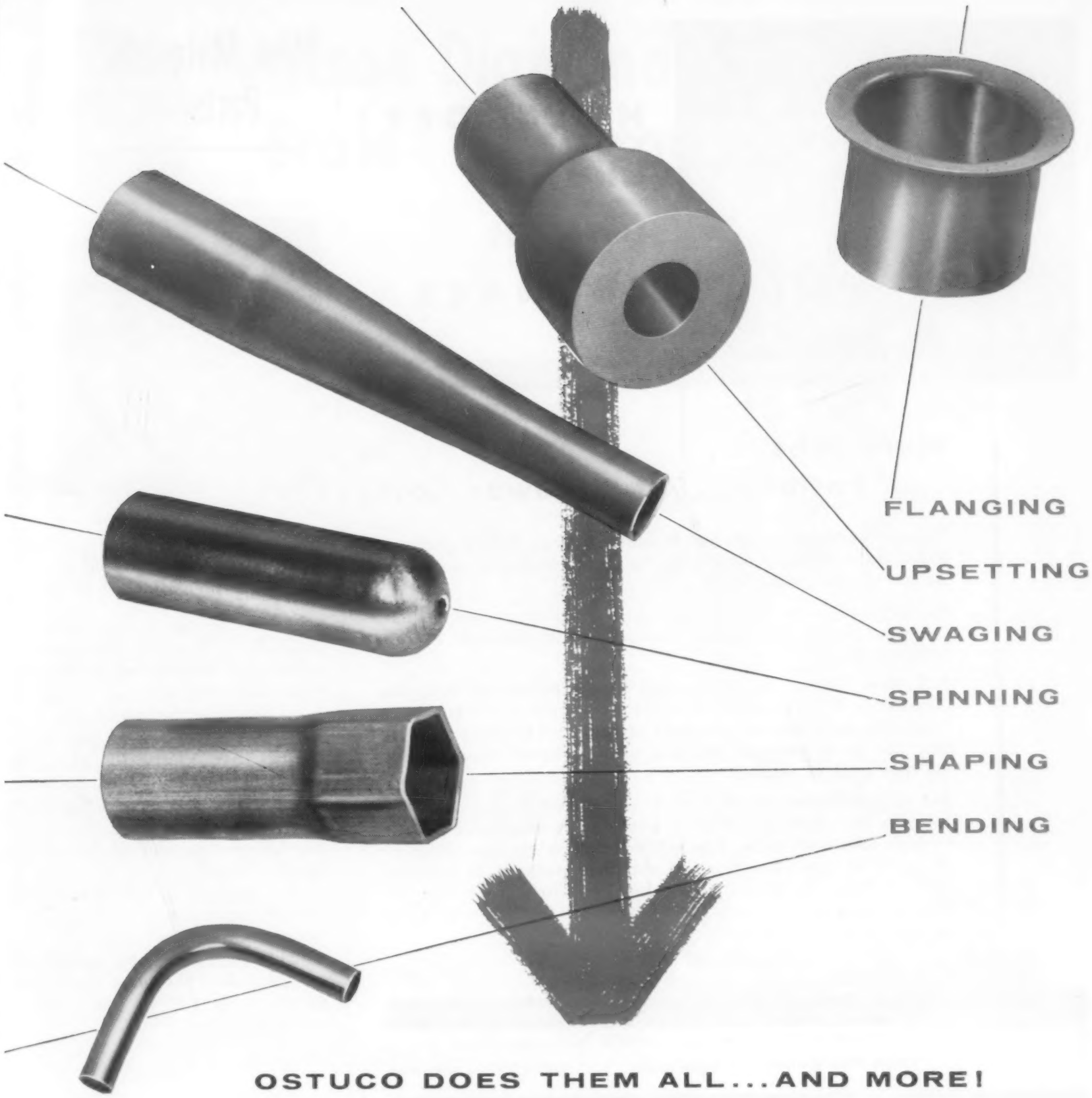
Alkaline Rust Remover

Developed by *Enthone, Inc.*, 442 Elm St., New Haven, Conn., Alka-Deox 114 is a free-flowing powder that is used in a concentration of 1 to 3 lb per gal of water. For rapid removal of rust, the compound should be heated to 180 to 212 F. According to the company, the alkaline solution will not attack the base steel, and paints, organic coatings and other surface contaminants are removed, together with the rust. It is recommended for the bulk derusting of steel and cast and malleable iron.

Rust Converter

Marketed by *Municipal Steel Co., Chemical Div.*, 1225 Broadway, New York 1, FerRoSeal is a cold phosphatizing treatment for rusted iron and steel. Developed by the *Walterisation Co.* of England, the material is said to chemically convert rust into a protective iron phosphate coating which forms a good base for paints. When used as a base for a coating the material is said to act as a bond and seal against further corrosion. According to the distributor, FerRo-Seal is compatible with asphalt, gilsonite, vinyls, silicones, neoprene, zinc base materials and other coatings as well as paints. One gallon is said to cover a metal surface area of about 1000 to 1500 ft, depending on the thickness of the rust.

(More New Materials on page 146)



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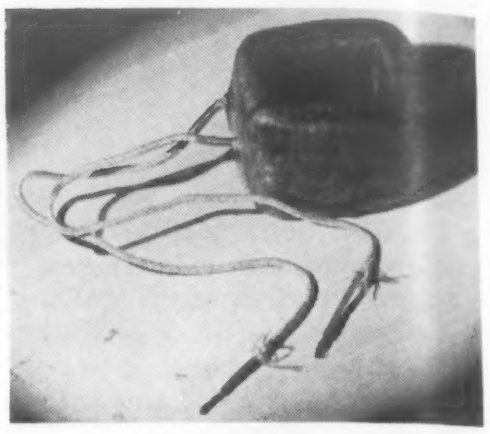
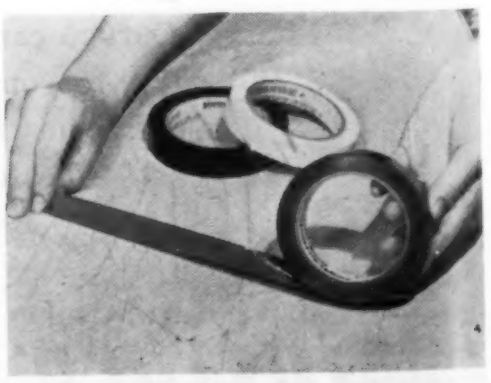
New Materials, Parts and Finishes



Low Cost Silicone Rubber for Cable Insulation

A new silicone rubber which can be fed into extruding equipment, requires no milling, needs no oven bake and is relatively low in cost has been developed by the *Silicone Products Dept., General Electric Co.*, 1 Plastics Ave., Pittsfield, Mass., for use as cable and wire insulation. Designated SE-965, the rubber is said to have good shelf stability, and electrical properties, and can be tinted in various colors.

The finished surface is said to be smooth and glossy, and the compound can be easily braided. It is suitable for Navy Cable and general commercial applications where temperatures of —65 to 300 F are encountered.



Pressure-Sensitive Plastic Tape Has High Strength

A new pressure-sensitive film tape possessing 25-lb tensile strength per in. of width, 100% elongation and 35-oz adhesion per in. of width has been marketed by *Minnesota Mining*

New Materials, Parts and Finishes

and Mfg. Co., 900 Fauquier St., St. Paul 6, Minn. The Scotch brand colored film tape No. 850 has a polyester film backing that the company claims has a relatively high degree of heat and chemical resistance.

Made with red, black or white pigments in its adhesive, the tape is said to resist attack by acids, alkalies, ketones, hydrocarbons, esters and other common solvents as well as all types of weather conditions. It is also said to retain its flexibility at low temperatures and to possess high dimensional stability despite heat and humidity changes.

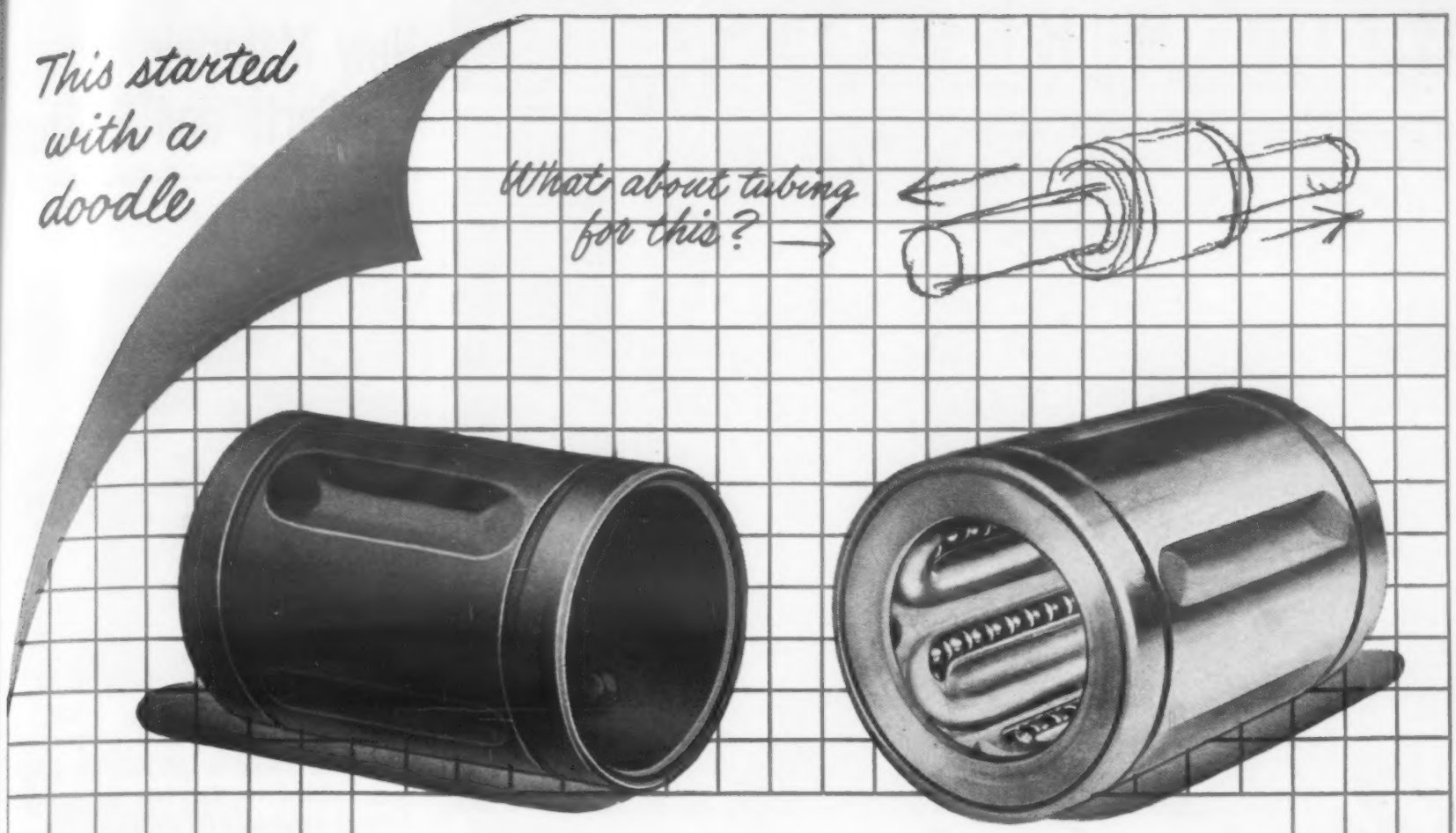
Uses for the tape are expected to be found in electroplating for stop-off masking jobs; metal fabrication for striping jobs; for decorative color striping and emblems of all types; and for general industry use where color marking is necessary. The tape is available in ¼-to 23-in. standard widths on 72-yd rolls. Other sizes can be produced on special order.

General Purpose Coating Has High Electrical Properties

A new air-dry spray coating is said to combine high physical, chemical and electrical properties making it suitable for a variety of electrical insulating uses as well as for spot corrosion protection. Marketed by *Insl-X Sales Co.*, 26 Rittenhouse Pl. Ardmore, Pa., E-26 spray provides a coat 0.75 mils thick with one spray stroke and the coat can be built up to any desired thickness by repeated application.

The resulting coat is said to have high arc and corona resistance, and to possess a dielectric strength of 800 to 1200 v per mil. It can be used to protect and insulate such equipment as bus bars, transformer and coil leads, motor coils, switchgear, starters and controllers. It will insulate and protect from moisture terminal boards, permanent electrical connections, fuse boxes and panelboards. It can also be sprayed on plant and equipment surfaces as spot protection against corrosion. E-26 is be applied by dip and brush as well available clear and in colors and may as by spray techniques.

(More New Materials on page 150)



Precision Tubing for Precision Jobs

Tubing tolerance is a big "must" on this job. Thomson Industries, Manhasset, N.Y., insists on it. Otherwise, manufacturing BALL BUSHINGS (ball bearings for linear motion) would have been even tougher than it was.

Part of the problem was the tubing to house the bearings and the raceway. Those bearings are very tough on tubing . . . especially at the contact points.

Other requirements were: good surface conditions; good dimensional control, both I.D. and O.D.; uniform wall thickness; uniform concentricity; and uniformity from a metallurgical standpoint to stand heat treating.

And, equally important, economy. By using ELECTRUNITE Tubing, Thomson Industries eliminates a grinding operation. That helps keep costs down.

The tubing that has all these advantages is Republic ELECTRUNITE, a *precision* mechanical tubing for applications like this. You can get it in carbon or stainless analyses. And Republic engineers will be glad to help you use it, profitably, in whatever products you make. Call your nearest Republic Sales Office or write to:

REPUBLIC STEEL CORPORATION
Steel and Tubes Division
218 East 131st Street, Cleveland 8, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, New York

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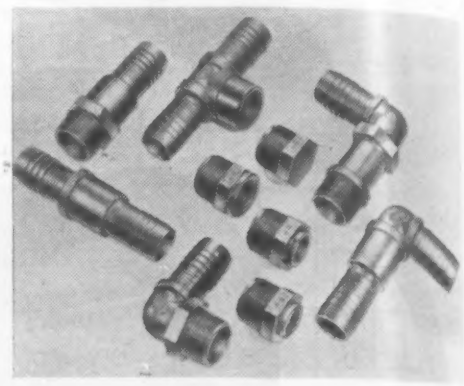
REPUBLIC STEEL

For more information, turn to Reader Service Card, Circle No. 370

New Materials, Parts and Finishes



Variety of Fixtures Joins Plastic Pipe

Twenty-seven special purpose fittings for flexible plastic pipe have been added to the line of standard fittings produced by *Franklin Plastics, Inc.*, Franklin, Pa. The new group is composed of extra length couplings, adapters and elbows for bacteria-free water well installations; long and short adapter elbows to simplify linkages used in jet pump hook-ups; and insert reducing tees with female threads in the stem.

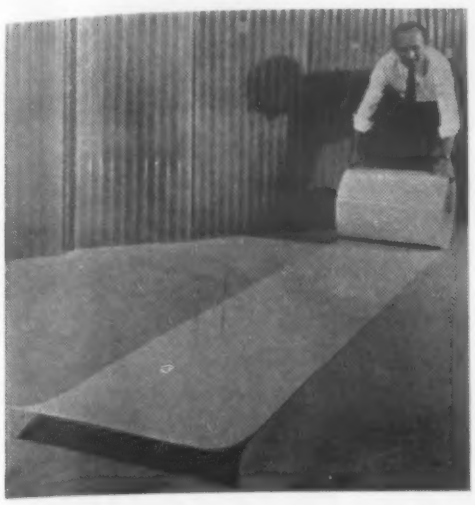
The well seal parts make it possible to seal water well casings germ-free at the top where the water pipes enter. The long and short adapters reduce the cost of water system installations. And the insert reducing tees are designed for use where it is necessary to branch from a plastic pipe with a smaller metal or plastic stem.

Aluminum Coating Protects Materials from Attack

A new coating has been developed which forms a protective shell of aluminum when applied to iron, steel, aluminum and wood surfaces. The coating is composed of atomized aluminum bonded to the surface with a fluxing vehicle. Developed by the *Industrial Div., the Woodhill Chemical Co.*, 1391 E. 33rd St., Cleveland 14, the coating can be sprayed or brushed on, will dry dust-free in less than 1 hr, and will fully cure in 6 hr. Called Duro Aluminum Shell Coating, it is said to be suitable for the protection of structural work, for coating porous castings and metal signs, and for automobile bodies. When used on wood it serves to guard against warping, checking and cracking.

For more information, Circle No. 399

New Materials, Parts and Finishes



Flat, Reinforced Plastic Sheet in Continuous Rolls

Flat, glass-reinforced polyester sheet is now being produced in continous roll form by *Plexolite Corp.*, 2051 E. Maple Ave., El Segundo, Calif. The sheet has an electronically-controlled uniform thickness, and the length of rolled sheet is limited only by shipping and handling needs.

The sheet shown above is 65 ft long, 24 in. wide and weighs 60 lb. Widths range from 12 to 40 in. and the material is available in 15 colors. The sheet is translucent making it suitable for sign and display backgrounds, and it can be easily sawed and drilled. Other applications include use in awnings, industrial skylights, glazing and translucent ceilings. It is said to be impervious to acids and shatter-proof.

Cold Degreasing Solvent Cuts Fire Hazards

A new nonflammable, low-toxicity solvent for cold cleaning and degreasing operations has been marketed by the *Dow Chemical Co.*, Midland, Mich. The material, Chlorothene consists of inhibited 1,1,1-trichloroethane, and according to the producer is well suited to those cleaning applications formerly requiring toxic, flammable solvents. Although 1,1,1-trichloroethane by itself may corrode aluminum and its alloys, the new inhibited grade is said to eliminate such corrosion under all except the most drastic conditions.

(More New Materials on page 152)

New Materials, Parts and Finishes

Two New Welding Electrodes: Automatic Operation, High Tensile Welds

Two new welding electrodes have been marketed, one a spooled wire for use with the inert-gas-shielded arc methods of automatic welding, the other a drag electrode for high tensile strength welds.

Spooled Wire for Automatic Welding

Spoolalloy, developed by *Pacific Welding Alloys Mfg. Co.*, 312 North Ave. 21, Los Angeles 31, is a welding electrode from which all oxides are said to be removed, reducing poor arc and poor fusion. The wire is precision wound, eliminating possibility of kinks and insuring a steady flow of wire to the welding head. It is particularly designed for sigma and heli-arc automatic welding. Spoolalloy is available in a range of alloys including aluminum, monel, inconel, stainless steel, phos-bronze and high carbon steels.

Drag Electrode Forms High Tensile Joints

Jetweld 2 HT, developed by the *Lincoln Electric Co.*, 22801 St. Clair Ave., Cleveland 17, Ohio, is especially designed for high speed welding of flat fillet and deep groove joints where high tensile strength and low crack sensitivity are required. Iron powder incorporated in the electrode's coating is said to provide speed and high performance.

The rod operates on either a.c. or d.c., although a.c. is recommended. Features claimed for the welding operation include good wash-in, slag removal and reduction of spatter to a minimum. Typical stress-relieved values for the new electrode are: tensile strength, 76,700 psi; yield, 64,300 psi; and elongation, 27%. Jetweld 2 HT is classified as E-7020 and is available in 7/32-in. diameters.

Two New Aluminum Casting Alloys Available in 50-Lb Pigs

Two new standard aluminum alloy pig products, designated alloy 2364 and 2393, are being produced in

New Materials, Parts and Finishes

50-lb pigs by *Kaiser Aluminum & Chemical Sales, Inc.*, Chalmette, La. The 2364 alloy is said to be a controlled high purity version of alloys A-108 and 319, used for permanent mold and sand castings. The 2393 alloy is a high-purity equivalent of 380 (AXS679), commonly used for die castings. New alloys may also be blended with secondary alloys.

The per-cent compositions of the alloys are as follows:

	2364	2393
Copper	3.5-5.0	3.0-4.0
Silicon	5.5-7.5	7.5-9.5
Iron	0.6-max	0.6-1.0
Other impurities, each	0.1 max	0.1 max

Advantages claimed for the new products include easier handling due to the 50-lb size, greater ductility in finished castings, and lower melting loss and improved machinability since alloys are made from prime metal only.

Ready-Mixed Adhesive Bonds Variety of Materials

A new industrial adhesive which requires no accelerators, catalysts or mixing has been developed to bond metals such as steel, aluminum, copper, brass and lead; structural materials such as concrete, brick, and wood; natural and synthetic rubbers; glass; paper; canvas and plastics including polyester, rigid vinyls and phenolics. Called Neoprene Adhesive F-1, the material is produced by the *Adhesive Dept., Carboline Co.*, 331 Thornton Ave., St. Louis 19, Mo.

The adhesive may be applied by spatula, brush or spray equipment and only good contact pressure is necessary to insure a strong bond. According to the company, the bond improves with age. When bonding neoprene sheet, a peel strength of 40 psi is said to be developed within 7 to 10 days. One of the exceptional features claimed for the adhesive is its ability to bond sponge rubber and rubber strip to metal such as gutter stripping, and weather stripping to door frames of automobiles.

Non-Toxic, Flexible Plastic Pipe

Made of 100% virgin polyethylene resin, a new light-weight flexible plastic pipe has been developed by

It's welded—

but you can't feel the weld

It has to be accurate

It's easy to fabricate

Specify Brainard FOR WELDED STEEL TUBING

• Brainard welded tubing is an economical structural material, and offers many physical advantages. It has a smooth exterior, with all weld flash removed. Its wall thickness is uniform, since it is formed from flat strip. With welded tubing you can cut weight without sacrificing strength. And there's practically no limit to the design requirements you can meet with this easily fabricated material.

Brainard maintains continuous quality control throughout manufacture—from ore to finished tubing. Careful supervision assures you high quality. For complete specifications call or write Brainard Steel Division, Dept. X-11, Griswold St., Warren, O.

Brainard

SHARONSTEEL

STEEL DIVISION
SHARON STEEL CORPORATION

* For more information, turn to Reader Service Card, Circle No. 380

New Materials, Parts and Finishes

Quaker Rubber Corp., Div. of H. K. Porter Co., Inc., Tacony and Comly Sts., Philadelphia 24. Designated the Series 200, the pipe is guaranteed to be non-toxic and it will not rot, rust or corrode. It is easily handled and economical. Typical applications include cold water systems, farm piping, sewerage, water service lines and means of conveying industrial chemicals and gases.

Two New Cleaning Compounds: Electrocleaner and Cold Cleaner

Two new cleaning compounds have been developed, one for electrocleaning of copper and steel, the other a water emulsion, which operates at room temperature and reduces plant fire hazards.

Heavy Duty Electrocleaner

Pennsalt Cleaner K-8 is a development of the *Pennsylvania Salt Mfg. Co.,* 1000 Widener Bldg., Philadelphia 7, and is designed to provide high detergent properties to remove mill oil and smut from steel and copper. It is a granular, anhydrous product containing 100% active ingredients which resist neutralization by acid soils and provide high electrical conductivity. The compound is recommended for use at 4 to 12 oz per gal, at 210 F with 75 to 100 amp per sq ft. Cleaning time will vary from ½ to 2 min depending on the application.

Cold Cleaner Cuts Hazards and Cost

A new cleaner which will operate at room temperature and is used in a water emulsion form has been marketed by *E. F. Houghton & Co.,* 303 W. Lehigh Ave., Philadelphia 33. According to the producer, it will eliminate fire hazards caused by highly volatile solvent cleaners in still tanks on the production line.

Other advantages claimed for the Houghto-Clean 402-403 are: removal of most generally encountered shop soil; protection of freshly cleaned surfaces from rusting between operations; elimination of heating system costs; and improved working conditions by the elimination of steamy atmospheric conditions associated with hot alkaline cleaning methods.

Contents Noted

A digest of papers, articles, reports and books of current interest to those in the materials field.

This Month:

- *New coatings for reactor materials*
- *French chromizing techniques*
- *Britain looks at plastics industry*
- *Properties of Thermenol*
- *Simple descaling of titanium*

Ceramic Coatings for Atomic Reactors

With the current developments in atomic energy for industrial use, there is an increasing demand for more information on materials to withstand the severe operating conditions in reactors. A new factor must now be taken into consideration which heretofore was disregarded; that is, neutron absorption of materials. If certain materials of construction in a reactor have high neutron absorption values those materials will interfere with the neutron barrage which is the basis of the chain reaction, and thereby restrict the action of the reactor.

Ceramic coatings to protect alloys used in the reactor from the high temperatures encountered (over 1800 F), must have neutron absorption values not exceeding those of the metals they protect. Results of an investigation carried out by J. C. Richmond, H. G. Lefort, C. N. Williams and W. N. Harrison of the National Bureau of Standards to develop such ceramic coatings are reported in a Summary Technical Report published by the NBS*. The most commonly used heat-resistant alloys for reactors were found to have thermal neutron coefficients ranging from 2.5 to 20 barns. Though the minimum value is desired, 3 barns was established as the reasonable maximum for the coatings.

Compositions of Promising Coatings, Parts by Weight

Coating No.	Frit		Refractory Amt	
	No.	Amt	Cr_2O_3	CeO_2
N-70	452	70	30.0	—
N-73	453	70	30.0	—
N-89	435	95	5.0	—
N-94	453	65	35.0	—
N-95	454	65	35.0	—
N-108	435	65	10.0	25.0
N-109	435	65	—	35.0
N-140	435	65	10.0	25.0
N-141	435	60	—	40.0
N-146	435	75	—	25.0
N-147	435	65	2.5	32.5
N-148	435	65	5.0	30.0
N-149	435	65	7.5	27.5
N-151	435	65	15.0	20.0

Optimum Coating Found

The most promising of the materials investigated are boron-free coatings of the frit-refractory type in which a high-barium frit is combined with ceria-chromic oxide. Boron in significant quantities is unacceptable due to its high neutron absorption value.

Of the various frits tested, the best results were obtained with NBS frit 435 and its modifications. Composition of frit 435 stated in molecular percentage is as follows:

SiO_2	51.02
BaO	25.51
CaO	6.12
ZnO	5.1
BeO	10.20
P_2O_5	2.04
Total	99.99
Average Neutron Absorption, barns:	0.192
Fritting Temp, F:	2600
Softening Point, F:	1462

The computed average absorption coefficients for the various modifications of this frit ranged between 0.15 and 0.25 barns, indicating that the boron-free frits were all satisfactory from this standpoint. The substitution of TiO_2 for SiO_2 increased the softening point and decreased the fritting temperature. It also increased the neutron absorption, but it still did not exceed 0.5 barns as compared to 3.0 barns or more for the base metals.

Using these frits, the most promising coatings contained cerium oxide or both cerium oxide and chromic oxide as the refractory component. The optimum ratio of frit to refractory was found to be 65 parts by weight of frit to 35 parts refractory, though good results are reported for 95 parts frit to 5 parts refractory. Most of the coatings contained 5 parts by weight of enameling clay used as a flotation agent.

High Temperature Testing

Most of the coatings that adhered well were tested to determine their value as thermal protection for various alloys. Those shown in the table below seemed the most promising. The samples were heated to 1900 F and cooled to room temperature a number of times in a series of irregular cycles. During the one-week trial, the samples were at the high temperature for a total of 150 hr. None of the coatings were outstanding when applied to type 321 stainless steel, though N-108, N-109, N-146, N-149 and N-89 gave appreciable protection. In addition to these coatings, those numbered N-94, N-95, N-141, N-148 and N-151 withstood the test in good condition on type 309 stainless steel. Most of these coatings as well as N-70, N-73, N-140 and N-147 performed well on type 310 stainless. Most of the coatings also showed good results when applied to Inconel.

Metallographic examination of tested and untested coated specimens revealed that some corrosion occurred beneath the coating in every case in the extended heating tests, but the amount of apparent depth of "stringer" corrosion was markedly reduced by the coating. In thermal shock testing all the coatings withstood water quenching to room temperature from 1100 F, and the best did not fail when quenched repeatedly from 2000 F.

**For reasons of economy, copies of the Summary Technical Reports are not available to the public. However, further information may be obtained by writing the National Bureau of Standards, Washington 25, D. C.*

(More Contents Noted on page 160)

Contents Noted

Chromizing metals in France . . .

French Developments in Chromizing Metals

The fields of chromizing and electrolytic chromium plating of metals overlap but do not coincide. Chromizing is generally most suited to the mass production of small and medium-sized parts, and less applicable to large plate and sheet. Service experience indicates that chromized parts are usually satisfactory for limited pressures such as in chains, but not for high pressures such as are encountered in drilling applications.

New developments in the O.N.E.R.A. chromizing process are the subject of two articles by P. Galmiche in the July issue of *Revue de Metallurgie,* this year. The process involves treatment in gaseous chromium fluoride at 1965 F for about 1½ hr to produce a layer about 0.004 in. thick with a maximum chromium content at the surface of 50% or more. Brilliant-type coatings are bright at the end of the treatment and relatively ductile. To obtain such coatings, medium and high carbon steels must be superficially decarburized before chromizing. To increase the surface hardness of this type of coating either nitriding or electrolytic chromium plating may be employed. Hard-type chromizing, on the other hand, depends on the carbon present in the steel being treated to produce a continuous layer of chromium carbide, which is very thin and hard. Both types of coatings have a high resistance to saline corrosion.

The relatively short treatment time reduces grain growth to a minimum; but core mechanical properties are reduced because the chromizing treatment constitutes an anneal for most ferrous materials. To avoid this, special alloy steels may be used or heat-treatable steels may be heat treated after chromizing. Heat treatment has an added advantage as it eliminates the brittle sigma phase that may be present in the outer chromium-rich layers. To restore the original brilliance, the heat treatment should be followed by a brief electropolishing cycle.

Applications on Various Alloys

Copper and copper alloys may be chromized if they are first coated with a metal capable of diffusing into both the copper and the chromium. In practice, a thick electrolytic nickel plate has been found to be satisfactory for this purpose. Chromized coatings are applied to copper alloys mainly to improve their acid resistance.

The chromizing process may be used to produce hollow unwelded parts. A piece of steel in the shape of the desired shell is chromized. The base steel is then removed by submersion in nitric acid, and since the chromized layer is resistant to nitric acid, a thin membrane of high chromium iron remains. Such parts have been found useful for altimeters and speedometers because of the absence of welds and brittleness.

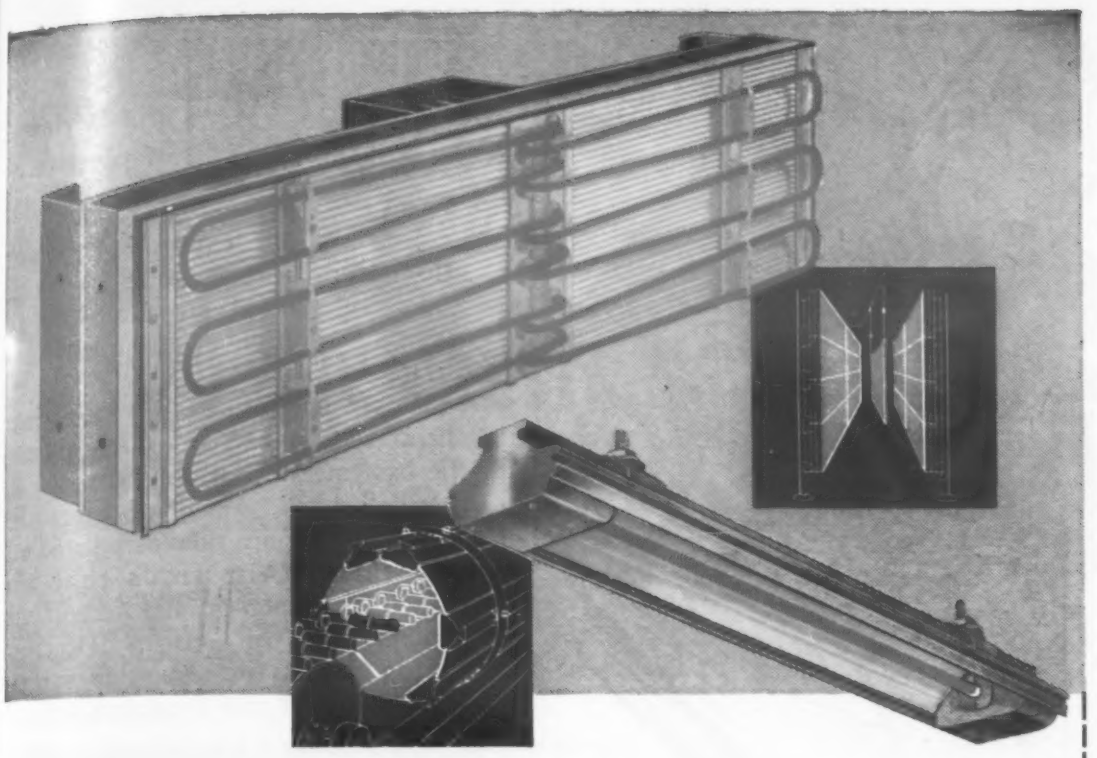
Chromizing may also be combined with other thermal treatments, such as sintering. Alloys such as Hastelloy B and the Nimonics may be simultaneously homegenized or solution treated and chromized. The

(Continued on page 162)

Applications of Chromized Coatings

Type of Protection	Diffused Metals	Examples of Treated Parts
Corrosion by products of combustion and dry oxidation	Chromium, silicon, aluminum.	Heat exchangers, burners, grates, gas-turbine parts.
Corrosion by nitric acid	Chromium, silicon.	Parts for nitric fuses and for the nitric-acid industry.
Humid, organic and saline corrosion	Chromium, silicon, zinc (immersion coatings of tin, aluminum, zinc*).	Bolts, dairy equipment, all parts in contact with humid atmosphere or sea water.
Wear	Chromium, silicon (carbon, nitrogen, sulfur).	Transmission chain, files, gages, piston rings.

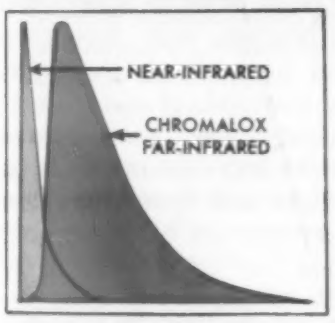
** The diffusion zone serves to bond the protective metal coating.*



CHROMALOX
Far-infrared
solves hundreds of heating problems

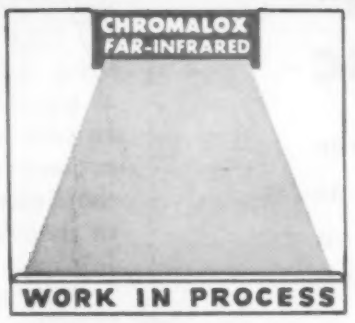
Here's your quick, economical and easy solution for curing, drying, degreasing, dehydrating, baking and other heating jobs. Pre-engineered Chromalox Units make oven building as simple as A-B-C, generate uniformly absorbed far-infrared heat for a multiplicity of processing needs. Temperatures up to 700° F. are easily selected, accurately maintained. Low initial cost, low write-off cost, low operating cost!

ONLY CHROMALOX GIVES YOU ALL THESE ADVANTAGES



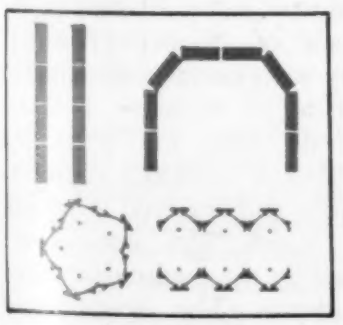
Color Blind Radiation

Longer far-infrared wave lengths are absorbed efficiently by all colors and textures.



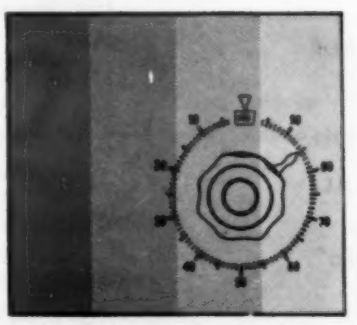
Heat Without Hot or Cold Spots

Chromalox radiant energy goes to work in a uniform pattern to span widest conveyor.



Low-Cost Oven Assembly

Pre-engineered Chromalox units require minimum expense to erect into complete ovens.



Infinitely Variable Heat Output

Heat from 0 to 100% of capacity to fit the exact temperature needs of the work.

plus

- **SHATTERPROOF CONSTRUCTION**—nothing to break or contaminate the work in process.
- **NON-DIMINISHING OUTPUT**—with all-metal Chromalox tubular far-infrared generators.
- **HIGH INTENSITY RADIATION**—with top BTUs per square foot.
- **QUICK HEAT-UP**—with energy transformed instantly into heat on the work.
- **ADDITIONALLY SAFE**-for any work involving volatiles.
- **MINIMUM MAINTENANCE**—Because of metal-sheathed, shock-resistant, long-lasting Chromalox tubular generators.

CHROMALOX *Electric Heat*
FOR MODERN INDUSTRY

DATA SHEETS
available to you on
APPLICATIONS OF CHROMALOX RADIANT HEAT

ABRASIVES
- ☐ R-111: Drying Silicon Carbide Discs
- ☐ R-122: Drying Abrasive Cloth

ASPHALT
- ☐ L-1055: Melting Korite Sealing Compound
- ☐ R-105: Heating Asphalt to Improve Sealing of Batteries
- ☐ RP-203: Drying Asphalt Tile

AUTOMOTIVE
- ☐ R-126: Drying Tractor Parts
- ☐ R-118: Baking Synthetic Enamel on Gasoline Engines
  Also see; Paint Baking

BATTERY
- ☐ R-105: Heating Asphalt to Improve Sealing of Batteries

BOTTLING (see Glass)

CERAMICS
- ☐ R-115: Drying a Water-Base Glaze on Ceramic Tile
- ☐ R-134: Preheating Dinnerware to Prevent Warping
- ☐ R-137: Drying Pottery

CHEMICALS (see Plastics)

COMFORT HEATING
- ☐ L-1077: Keep Men Warm, Keep Work on Schedule
- ☐ R-114: Comfort Heating for a Foundry Worker

DEGREASING
- ☐ R-116: Vaporizing Oil from Sheet Metal Parts
  Also see: Paint Baking

DRUGS (see Glass)

ELECTRONICS
- ☐ R-109: Drying Cement Base in Television Tubes

FINISHES (see Paint Baking, Degreasing)

FOUNDRY
- ☐ L-1060: Skin Drying of Molds
- ☐ L-1085: Core Drying
- ☐ L-1096: Shell Molding Goes Automatic
- ☐ R-115: Comfort Heating for The Foundry Worker
- ☐ R-130: Drying Precision Plaster Molds
- ☐ R-135: Shell Molding

GLASS
- ☐ C & R-2: Sterlizing & Preheating Bottles
- ☐ R-127: Heating Television Tubes to Bake Interior Graphite Coating

PAINT BAKING
- ☐ L-1064: Drying Lacquered Metal Parts
- ☐ L-1065: Improves Enamel Baking Five Ways
- ☐ L-1066: Bakes Big Parts or Small, Fast or Slow
- ☐ L-1080: Baking Paint on Radiators
- ☐ R-118: Baking Synthetic Enamel on Gasoline Engines
- ☐ R-119: Baking Paint on Metal Awnings
- ☐ R-131: Baking Paint on Meter Parts
- ☐ R-138: Drying Ink and Paint on Toothpaste Tubes

PAPER
- ☐ R-134: Drying Glued Paper Sheeting

PLASTICS
- ☐ L-1086: Drying Vinyl Coating on Imitation Leather
- ☐ L-1091: Post-Forming Formica
- ☐ R-101: Molding Kapok Center for Softballs
- ☐ R-102: Drying Plastic Powders
- ☐ R-104: Preheating Micarta Strips for Punching
- ☐ R-121: Dehydrating Vinyl Sheets
- ☐ R-123: Drying Plastic Laminates
- ☐ R-128: Curing Plastic Coating on Spring Clips
- ☐ R-129: Fusing Vinyl to Chip Board
- ☐ R-132: Embossing Vinyl
- ☐ RP-210: Heating Plexiglas for Vacuum Forming
- ☐ RP-202: Heating Thermoplastic for Vacuum Forming

PRINTING
- ☐ L-1090: Silk Screen Process Drying
- ☐ R-103: Static Removal
- ☐ R-107: Drying Ink on a Miehle Vertical Press
- ☐ R-108: Ink Drying on 8-Unit Web-Fed Offset Press
- ☐ R-110: Eliminating "Offset" on Duplicating Machines
- ☐ R-124: Drying Ink on a Goss Press
- ☐ R-136: Silk Screen Process Drying

REFRIGERATION
- ☐ L-1055: Dehydrating Refrigerator Coils

RESTAURANT
- ☐ Far-Infrared Food Warmer

RUBBER
- ☐ L-1056: Curing Latex Foam Sponge Rubber
- ☐ R-125: Cementing Crepe Rubber to Wooden Soles

TEXTILES
- ☐ L-1068: Fusing Vinyl to Cloth Work Gloves
- ☐ R-112: Dehydrating Braiding Material

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chromized layer then protects the base alloy from intergranular oxidation and scaling so full advantage may be taken of its high creep and rupture strengths.

It is also pointed out that since chromized layers are diffused into the base metal, they are insensitive to thermal shock. Frictional properties of the coating are now being studied, and the author finds that the O.N.E.R.A. method has certain advantages over the German BDS chromizing process in respect to surface brilliance, cost and treatment time.

A British View of the World Plastics Industry

When the word "plastics" appeared in technological and scientific circles in the mid-twenties the science of chemical synthesis was in its infancy. Synthetic products were generally viewed with doubt, as substitutes which should be used only when the real thing was not available. However, the chemists' pioneering in the field persevered, and finally, during the years prior to World War II, these materials were first given their chance to establish themselves as specialist materials of construction. In the ensuing war years plastics proved themselves as materials in their own right and opened the door to their acceptance as basic engineering materials.

This view of plastics in retrospect was stated by Dr. V. E. Yarsley, President of the Plastics Institute (British), at the 1954 Annual General Meeting of that society. A summation of his review of the world plastics industry was published in the August issue of *Plastics* (British). Dr. Yarsley went on to point out that use of plastics in industry, as apart from domestic uses, has developed the conception of judicious engineering in design and material selection, a quality which was not always characterized by the manufacturers of consumer items. The development of this concept was aided by the cooperation between industry and the government in developing specialized materials to meet specific military needs. This specialized development has given impetus to the general development of plastics, and end-product design has progressed in

(Continued on page 166)

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Contents Noted

British view of plastics...

the past decade in directions which would have been impossible without plastics materials.

A Glance at World Production Statistics

Though he points out that statistics of plastics production are not too dependable for the pre-war years, Dr. Yarsley states some figures briefly in order to put the plastics industry in its proper perspective. Celluloid, the pioneer of plastics materials, by 1935 had attained a world production of 30,000 tons, and by 1937 plastics production in the U. S. was around 95,000 tons; in Germany, around 65,000 tons; and in the United Kingdom, around 27,500 tons.

The war years of 1939-1945 completely altered the appearance of the production charts with the development of new materials such as polyethylene, production of which by 1945 had increased 19 times the volume produced in 1940. Recent months have shown evidence of the re-entry of Japan and Germany into the world plastics production. The recent Overseas Economic Survey gives the value of manufactured plastics exported from Japan in 1951 as $3,133,285, and West German production rose from 48,000 tons in 1948 to 225,000 tons in 1953. This figure is in comparison with 186,000 tons for the U. K., and if correct indicates that Germany ranks second only to the U. S. in world production of plastics.

The Economic Picture

In assessing the financial standing of plastics, Dr. Yarsley emphasized that plastics are a part of the chemical industry. The demand of raw materials for plastics, such as the styrene monomer for synthetic rubber, has catalyzed the growth of such industries as the petrochemical. And these in turn have provided invaluable sources of the basic materials for plastics.

In attempting to evaluate the monetary worth of the plastics industry to the individual countries, Dr. Yarsley quotes figures from the U. S. Tariff Commission. U. S. production of plastics in 1947 was 1.3 billion lb, valued at $450 million; in 1951 it was 2.4 billion lb, valued at $700 million; and in 1952 it was 2.3 billion lb, valued at $750 million. Coordinating these figures with others for the chemical industry, Dr. Yarsley concludes that plastics should account for roughly 10% by weight of U. S.

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

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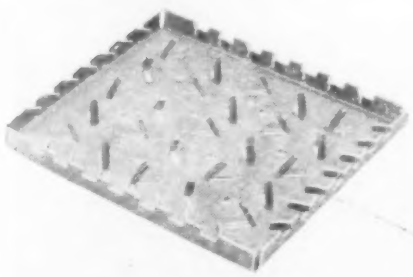
LEHIGH H DIE PRODUCES INTRICATE FLOOR-PLATE SECTION



The picture at the upper right shows the business end of a large blanking-and-forming die, used in making floor-plate sections for Flash-Stone Company, Inc., Philadelphia. The photograph below shows 11-gage sheet steel being fed into an 850-ton press, beyond operator, where it undergoes initial blanking and forming. Additional forming, plus trimming, are done in a return pass, at operator's left. Above appears the finished product, an 11¾-in. square, with numerous lugs on the top and sides for gripping the concrete.

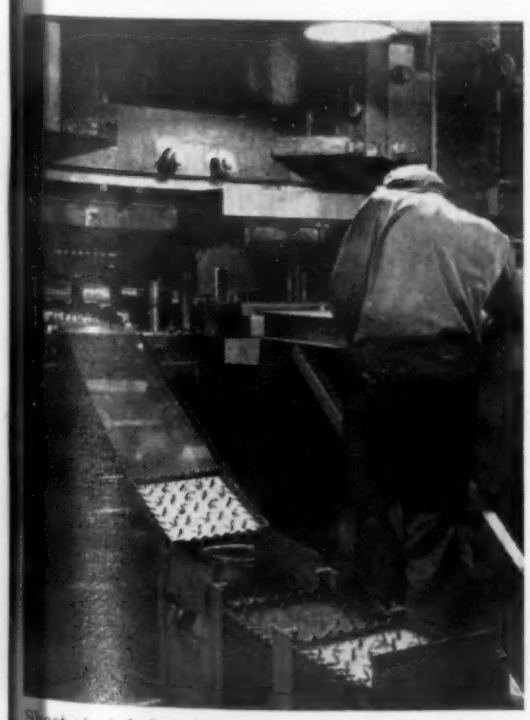
The die, made of Lehigh H tool steel, is providing long production runs because of its good resistance to wear and shock. Redressing is seldom required.

Lehigh H is a high-carbon, high-chromium, air-hardening tool steel, well known for its easy machinability and easy heat-treatment. It's a deep-hardening steel, too, with high compressive strength.

TYPICAL ANALYSIS

Carbon	1.55	Molybdenum	0.80
Chromium	11.50	Vanadium	0.40

Like to prove to yourself how Lehigh H Tool Steel wears . . . and wears . . . and wears? Call your tool steel distributor, or write a line direct to us at Bethlehem, Pa.



Sheet steel, being fed into press for initial blanking and forming, is further formed and trimmed on the return pass into the finished floor plate, which is shown on the slide near foot of picture.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Use Distortion Tests With Care

Distortion of tool steel in heat-treatment is a phase of toolmaking which is often misunderstood. And some of the available distortion-test data adds to the confusion.

Typical of the misleading distortion tests are those on bar stock, about ¾ in. round and 1 in. long. The results are reported as the change in length occurring in the hardening heat-treatment, and certainly do tell what happens when steel of that size is hardened. But how to use this data to predict size changes of tools of other sizes? There's the rub!

The test described implies that the distortion figure for the 1-in. piece can be applied elsewhere—for example, that a 5-in. piece changes 5 times as much, and a 10-in. piece 10 times as much. Not so! Depending on the size and shape of the pieces being hardened, expansion or contraction may occur, but the factor cannot be used to predict which. Therefore the data obtained on the test piece is of limited value, as it applies only to the hardening of tools of the size and shape of the test piece itself. There is no such thing as a single test specimen which predicts size changes in tools of various sizes and shapes.

If you would like additional information on distortion, write for a copy of our article, "Distortion of Tool Steels in Heat-Treatment."

organic chemical production. The most reliable British figures indicate that plastics make up about 20% of the total chemicals exported from that country. The doctor cautions, however, that these statistics were gathered from a number of sources and are used only to indicate primarily the importance of the plastics industry to the national economies, and also the trends in plastics development.

What's Ahead?

Plastics are already a significant part of the giant chemical industries of the world, and according to Dr. Yarsley, will assume ever-increasing importance in the over-all industrial and economic structure. In the U. S., polyethylene is said to be the first plastic whose production volume alone topped the million-ton-per-month mark. As for PVC, and its copolymers, they early hit the high peak in the U. S., but for long remained "the inferiority complex of plastics" in Britain. However, the recently opened Bakelite plant there has now brought production in the U. K. to around 40,000 tons per year. British polystyrene production capacity is said to be around 18,000 tons per year, in spite of monomer difficulty.

As to the question of new plastic materials in the future, Dr. Yarsley states that though it is certainly possible to develop new basic resins, their properties would probably not be greatly different from those already developed. He seems to feel, as do many others in the industry, that the efforts of chemists, physicists and engineers should be concentrated not on developing new basic resins, but rather on finding practical uses for the profusion of resins already available.

Properties of High Temperature Iron-Aluminum Alloy

Thermenol, a nonstrategic iron-base alloy containg 16% aluminum and 3.3% molybdenum has been developed by the U. S. Naval Ordnance Laboratory as an oxidation resistant alloy that might be suitable for use at elevated temperatures in the range of 1100-1200 F. The accompanying tables show values for stress-rupture and tensile strength gathered during preliminary investigation by the NACA Lewis Flight Propulsion

Contents Noted | Thermenol... Flexible plastics . . .

Lab in cooperation with the Naval Ordnance Lab. This data was published as a Research Memorandum by the National Advisory Committee for Aeronautics in August of this year. The properties of AISI 310 and 321 are given for purposes of comparison.

Room Temperature Ultimate Strength of Thermenol Compared with AISI 310 and 321

Alloy	Stress, psi	Elong, %
Thermenol	Avg 62,050	Avg 3[a]
AISI 310	92,000	47[b]
AISI 321	96,000	58[b]

[a] *¾-in. gage length. Broke outside gage length.*
[b] *2-in. gage length.*

High Temperature Stress-Rupture Strength of Thermenol

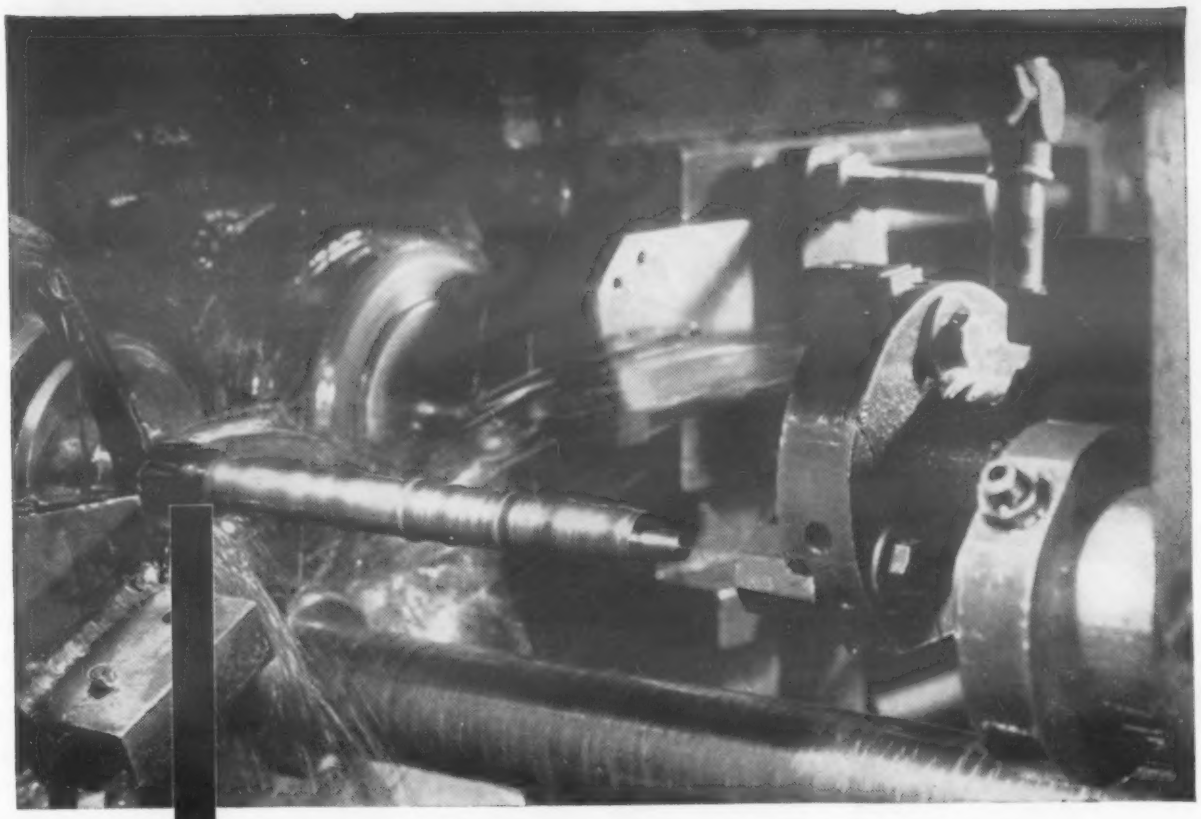
	Rupture Stress, 1000 psi			
	at 1100 F		at 1200 F	
Time, hr	100	1000	100	1000
Thermenol	35.5	23.0	19.5	10.0
AISI 310	31.5	25.0	19.0	13.5
AISI 321	40.0	26.0	26.0	17.5

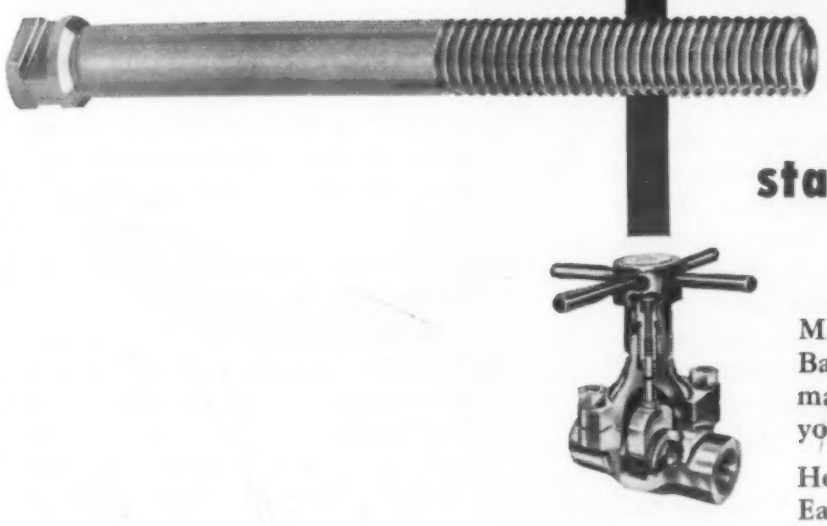
Molding and Extrusion of Flexible Plastics

The term flexible plastics is coined here to mean plasticized compounds of polyvinyl chloride and its copolymers, and polyethylene. These materials and particularly the PVC compounds are of vital interest to the rubber industry since they are competitive in many applications. In a paper delivered before the Annual Conference of the Society of the Plastics Industry in June of this year, Frank A. Martin of the Hoover Co. discussed some aspects of compounding, molding and extruding these materials.

PVC Compounding and Forming

Before PVC resins can be used for either molding or extrusion they must





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Here's how one manufacturer does it: Edward Valves, Inc., East Chicago, Ind., makes a new MUDWONDER Valve used in the oil fields. It must have high resistance to corrosion and long life.

Valve stems are made of ENDURO Cold Drawn Types 410 and 416. And Edward methods engineers say they get good production for these reasons:

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You can have these same advantages in your stainless steel parts, by specifying ENDURO Cold Drawn Bars. And Republic metallurgists will be glad to help you choose the right grades for best production on your present machines. Write to:

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Contents Noted

Flexible plastics . . .

be compounded with other materials such as plasticizers, stabilizers, fillers and lubricants. The resulting compound may be either in granular or powder form. PVC compounds are usually molded by the injection process. Good moldings can be obtained using either the granular or dry-blend compounds. There are two basic factors that must be kept in mind when molding the material: first, the heating cylinder temperatures necessary for plasticizing vinyl compounds approach the decomposition temperatures; second, PVC compounds have a lower heat transfer coefficient than most other thermoplastics. The basic problem, then, is getting sufficient heat into the material to render it moldable without overheating to the point where decomposition sets in. Heating chamber temperatures usually range from 350 to 375 F. Furthermore the judicious selection of nozzle and gate sizes enables the molder to efficiently utilize frictional heat in gaining consistent temperatures throughout the material.

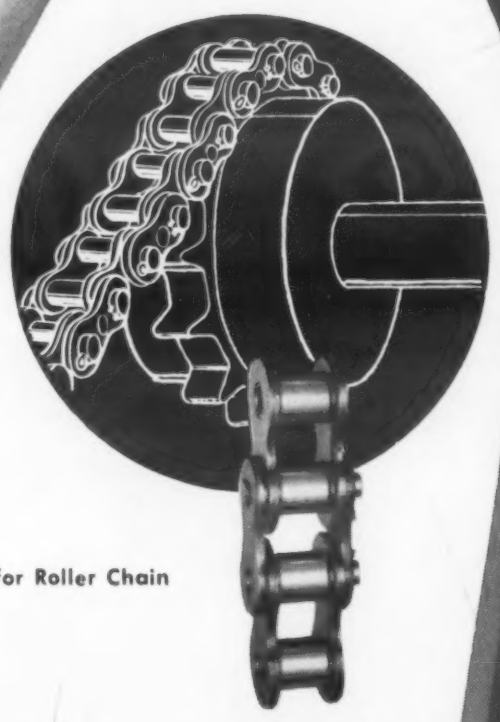
Industry has found that the use of the screw type extruder offers several advantages in plasticizing flexible vinyl compounds. It results in a more thorough, uniform plasticizing action, producing better surface finish and gloss; plasticization occurs at a lower machine temperature as a result of the frictional heat, which means less danger of material decomposition; and it greatly increases plasticizing capacity resulting in more cycles per hour.

According to the author, the art of extruding flexible PVC is much more highly developed than is the molding operation. Here again, the compounds may be either in granular or powder form. The lower heat transfer rate of the dry blends in comparison to granular compounds affects the extrusion conditions required. With a granular feed, the extruder zone temperatures will generally run from 300 F at the feed end to 350 F at the end of the screw, with 350 to 360 F die temperatures. Dry blends require somewhat higher barrel temperatures in the range of 400 F.

The ease with which flexible PVC compounds may be extruded without subsequent vulcanization as is necessary with rubber makes it a formidable competitor in applications where the vinyl properties permit it to be used. Flexible PVC is now being

For more information, Circle No. 333

Pressure Cartridge in a Fire Extinguisher



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Why not investigate the possible use of Globe tubing in your product? Globe's "one-source" supply offers seamless carbon, alloy, and stainless tubing in a complete range of sizes and analyses. Globe metallurgists and engineers are available to assist in the proper selection of tubing for your particular job. Write for the Globe General Catalog.

Producers of Globe seamless stainless steel tubes — Gloweld welded stainless steel tubes — alloy — carbon — seamless steel tubes —Globeiron (high-purity ingot iron) seamless tubes — Globe Welding Fittings

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used in such applications as garden hose, wire coating, refrigerator door gaskets and channel strips for storm sashes. The tubing is being used as laboratory tubing, beer tubing, plasma tubing and aircraft wiring ducts.

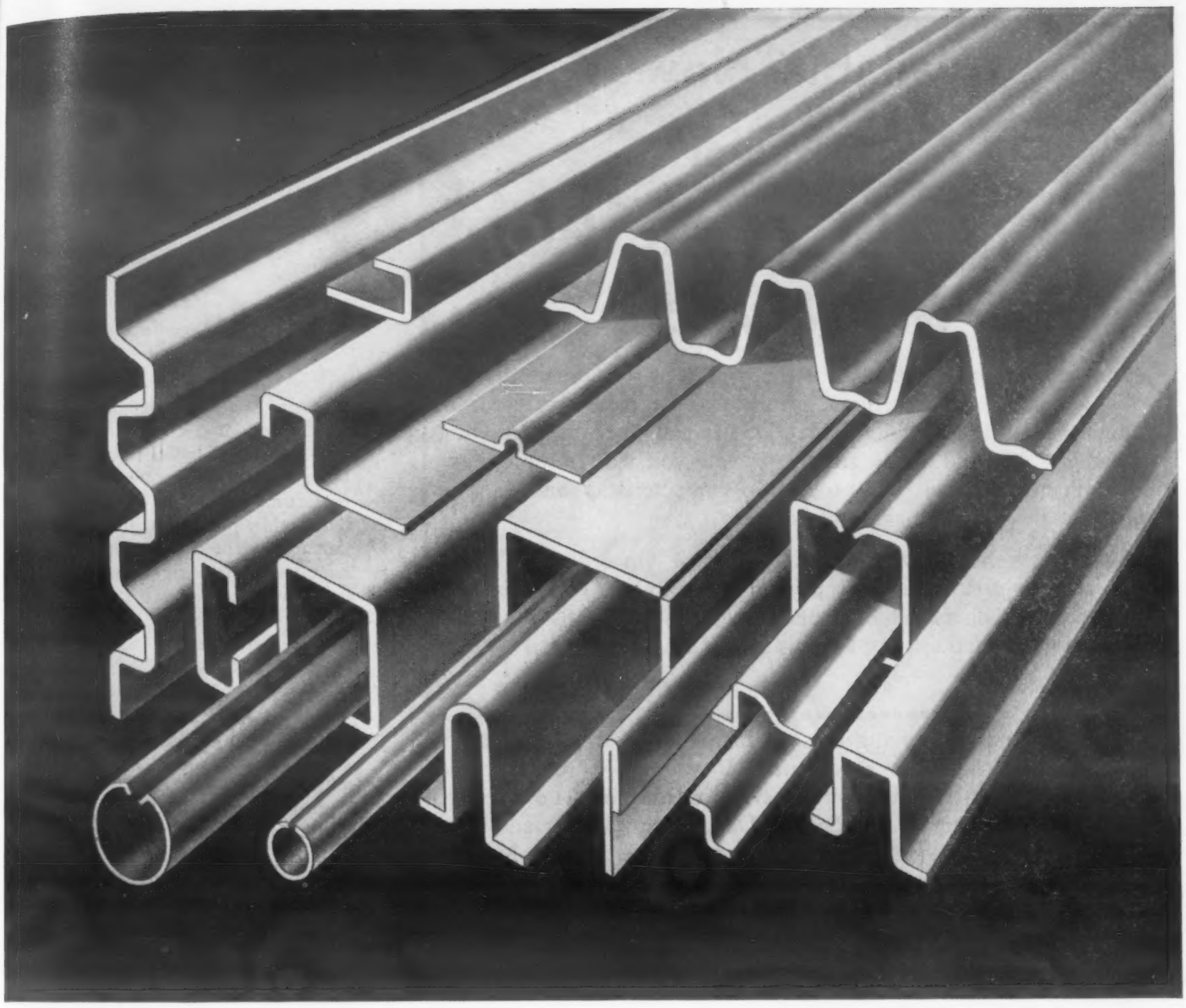
Polyethylene Forming and Applications

Although polyethylene may be construed to be a flexible plastic it is not so directly competitive with rubber. It is easy to mold by the injection process and does not readily decompose at processing temperatures. Perhaps the biggest problem in molding polyethylene is control of shrinkage. Shrinkage may be varied widely by control of material and temperatures and of injection pressure.

Polyethylene has high dielectric properties, good aging and low water absorption; it is odorless, tasteless, light weight, unbreakable and is resistant to chemicals. One large application for molded polyethylene has been in housewares such as bowls, refrigerator dishes and other kitchen utensils. It is being used for piping, wire covering and blown film. The latter has found wide usage in the packaging industry since it is a good moisture barrier and can be readily heat-sealed. A further extension of use of the material may come about through the use of irradiated material. Such exposure brings about a molecular cross-linking which in effect "vulcanizes" the material and raises the softening temperature to 330 to 350 F or higher.

Simple Pickle Descales Titanium

The development of a pre-treatment consisting of certain carbonates combined with certain nitrates promises to allow the descaling of titanium by a simple pickling operation. During heat treatment, titanium and its alloys form oxide scales which vary in composition with the temperature of treatment. As the temperature increases, the tenacity of the oxide scale increases. With heat treating temperatures of less than 1000 F, the resulting scale can be pickled off. Today, however, temperatures in the range of 1100 to 1400 F are common,



Which One of These Cold-Formed Shapes Could You Use?

The variety of Cold-Formed Shapes you see above are only a few of the great diversity of shapes Bethlehem can turn out. In each case, the shapes above represent savings in time and money to customers, who used them in an equally varied number of end-products.

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If you are already using Cold-Formed Shapes or have an idea for a new shape, our experienced sales engineers can often suggest modifications to permit more economical production. Because of Bethlehem's complete facilities, there is no need for large inventory at your plant—we can make and ship your product as you need it.

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For large or recurring runs, it will be to your advantage to have special rolls made in our machine shop. Or we may already have rolls in stock to suit your needs.

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BETHLEHEM STEEL

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and after treatment in this temperature range, the tenacity of the scale is such that the tendency is for the titanium to dissolve out from under the scale.

New Process Developed

The new process, described by Bryce Chambers, Process Engineer, Boeing Airplane Co., involves the application of a crystalline pre-treatment which chemically converts the scale built up during heat treatment to a form which can be conveniently removed by pickling without excessive damage to the parent metal. It was found after investigation that certain carbonates combine with some nitrates to furnish an effective treatment. The nitrates are believed to oxidize the scale oxides into higher oxides or ones of different crystalline structure. The carbonates are believed to convert the normal or converted oxides into titanates. The resulting scale adheres so loosely that a portion of it usually cracks off upon cooling. The remainder can be pickled off in a single modified nitric-hydrofluoric acid pickle solution.

Descaling can usually be accomplished in less than ten minutes. Some discoloration is encountered in the form of a slight cloudiness in spots, but it should not be detrimental unless a highly lustrous surface is required. The finished surface is weldable and no intergranular corrosion occurs.

(Book Reviews on page 178)

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These Impact Forgings are shown three-fourths actual size

These aluminum thick bottom cans were formerly machined from bar stock at great cost—now impact forged by Hunter Douglas to final print in one fast operation at low cost. The parts are illustrative of the endless variations in part geometry possible with Hunter Douglas cold impact forging. The "no-draft" characteristic effectively eliminates machining. Simply trim to length, drill holes in base for attaching bolts and the part is ready for final assembly.

To the economies achieved through impact forging can be added the superior physical properties resulting from this mass production technique perfected by Hunter Douglas. Increased fatigue properties are obtained and bending stresses at the inside corners are redistributed parallel to the flow lines rather than cross grain as would be the case if the part were machined from bar stock.

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For more information, turn to Reader Service Card, Circle No. 475

Contents Noted | Books

Strength and Resistance of Metals. *John M. Lessells. John Wiley & Sons, Inc., New York 16, N. Y., 1954. Cloth 6 by 9 in. 450 pp. Price $10.00.*

This book has been written to discuss the behavior of metals under stress. The discussion is centered around steel although some information on nonferrous metals is included, particularly where the behavior of the two types differs.

The subject matter is covered in eleven chapters beginning with a discussion of tension and compression, with particular emphasis on elastic properties. Other chapters discuss hardness, impact, fatigue, the fracture of metals, wear and theories of strength and working stresses.

The book is intended for use as a text at the undergraduate senior level or the graduate level and therefore contains a section on problems to be worked in conjunction with each chapter. However, the design engineer will find much valuable information.

The Light Metals Handbook. *George A. Pagonis. D. Van Nostrand Co., Inc., New York, N. Y., 1954 (in two volumes). Cloth, 6 by 9 in. 432 pp. Price $8.50 per set.*

This book is published in two volumes, one containing the text, the other containing related tables with the objective of permitting the reader to have before him, any specific table referred to in the text. Each volume is divided into two parts. Part 1 covers magnesium and magnesium alloys. Part 2 deals with aluminum and aluminum alloys. Organization in each part of Volume 1 is similar. A section on classification is followed by chapters on mechanical properties and physical properties in general, detailed properties on specific alloys, forming, fabrication and alloy selection. Volume 2 contains 93 tables on magnesium alloys and 138 tables on aluminum.

This book will be very useful to the materials engineer concerned with the light metals, although a section on titanium would have added to its value.

Materials of Construction. *M. O. Withey and G. W. Washa. John Wiley & Sons, Inc., New York, N. Y., 1954. Cloth, 6 by 9 in. 870 pp. Price $9.00.*

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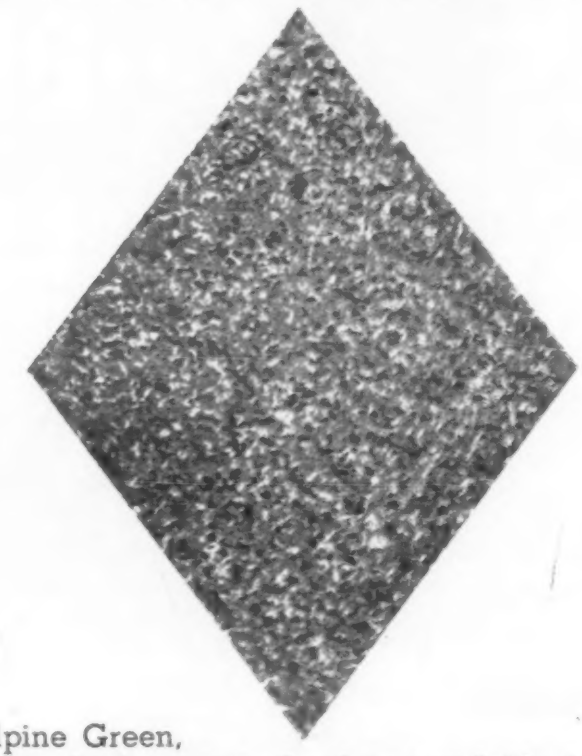

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Contents Noted | Books

work retains the original aim of presenting a book which can serve both as a text and reference book. It has been extensively revised to present the latest data on the sources, manufacture and fabrication of the principal materials of construction.

The book is divided into 32 chapters, thirteen are devoted to a discussion of the characteristics of wood, stone, clay, cement, concrete and similar materials. Eleven chapters deal with ferrous alloys and two with nonferrous alloys. An extensive list of references adds to the value of the volume.

Fiberglas Reinforced Plastics. *Ralph H. Sonneborn. Reinhold Publishing Corp., New York 22, N. Y., 1954. Cloth, 6 by 9 in. 240 pp. Price $4.50.*

This is the first book in which the reinforced plastics are discussed in a comprehensive manner. It covers the resin and glass reinforcements used in reinforced plastics, molding techniques, properties, inspection and testing and design considerations.

The book is divided into two parts. Part one covers the materials, their processing, their properties and design methods based on experience. Part two deals with the theory of design with reinforced plastics. A bibliography of the field is given as an appendix.

The book will be valuable to the design engineer and executive in the materials industry particularly, but will also serve as a convenient reference work for those interested in the application of plastics.

Modern Plastics Encyclopedia, September, 1954. *Breskin Publications, New York, N. Y., 1954. Cloth, 8½ by 11½ in. 955 pp. Price: Available only to subscribers of* Modern Plastics *Magazine.*

The fourteenth annual edition of this standard reference on plastics materials and production methods incorporates basic data on the many new materials and processing techniques that have been developed during the period between editions. New additions include special chapters on vacuum forming, reinforced plastics, plastisol molding and a fully revised series of charts covering the properties and processing peculiarities of plastics resins and compounds. Major topics covered are: Engineering and Methods, Resins and Molding Compounds, Machinery and Equipment, Chemicals for Plastics, Fillers and

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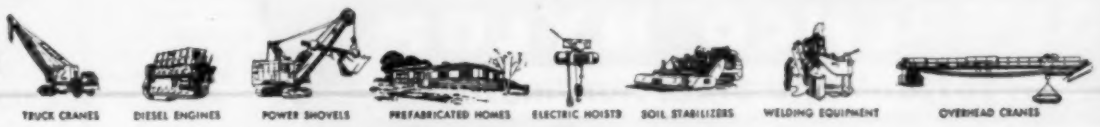

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Contents Noted | Books

Reinforcements, and an extensive 121 page Buyers' Directory of suppliers of equipment, materials, supplies and services.

ASTM Standards on Wood, Wood Preservatives, and Related Materials. *American Society for Testing Materials, Philadelphia, Penna., 1954. Paper, 6 by 9 in. 366 pp. Price $3.75.*

For the first time, the American Society for Testing Materials has combined in one compilation the ASTM specifications, test methods, and definitions of terms pertaining to wood, wood-base materials and wood preservatives. Sponsored by ASTM Committee D-7 on Wood, the compilation includes 59 ASTM standards, including 43 test methods; 11 specifications; 3 definitions of terms relating to timber, timber preservatives, and veneer and plywood; and 2 others: one for the nomenclature of domestic hardwoods and softwoods, the other, the volume and specific gravity correction tables for creosote and coal tar.

Monomeric Acrylic Esters. *Edward H. Riddle. Reinhold Publishing Corp., New York, N. Y., 1954. Cloth, 6 by 9 in. 221 pp. Price: $5.00.*

Beginning with a brief history of acrylic monomers and polymers, the author then discusses the physical properties of both the technical grades and purified materials. Subsequent chapters describe methods used to polymerize monomeric acrylic esters, their copolymerization with other commercially available monomers, the uses of acrylic esters as intermediates in chemical reactions other than polymerization and methods of determining the purity of monomers. Recent advances are covered in all chapters and particular attention is directed to the latest theories of polymerization and copolymerization mechanisms involving monomeric acrylic esters.

Study on Aluminum Extrusions. *G. Roger Smith. Harvey Aluminum Co., Torrance, Calif., 1954. 8½ by 11 in. 36 pp. Price: Available by request on business stationery, additional copies, $1.50.*

Here is a comprehensive study of aluminum extrusions the purpose of which is to point out the vast and extensive uses to which extrusion can be applied in new design and to aid

those now using aluminum extrusions in improving existing designs. Technical material includes current applications, design advantages, fabricating, finishes, general characteristics. Data charts, illustrations and sketches are used extensively.

Welding Alcoa Aluminum. *Aluminum Company of America, Pittsburgh, Penna., 1954. Paper, 5½ by 8½ in. 176 pp. Available without charge on company letterhead.*

This booklet reflects the many new changes in the technology of welding aluminum alloys. In addition to the basic, practical information on the individual processes, it offers data on choice of method to assist the welding engineers, shop men and designers at the time when decisions are being formulated.

Progress in Metal Physics, Volume V. *Edited by Bruce Chalmers. Interscience Publishers, New York, N. Y., 1954. Cloth 6 by 9½ in. 317 pp. Price $9.50.*

Presented here are authoritative reviews of the present state of knowledge in specialized aspects of the field that include both physical metallurgy and metal physics. The fifth volume in this series includes such topics as: *The Fracture of Metals* by N. J. Petch; *Geometrical Aspects of the Plastics Deformation of Metal Single Crystals* by R. Maddin and N. K. Chen; *The Structure of Liquid Metals* by B. R. T. Frost; *Report on Precipitation* by H. K. Hardy and T. J. Heal and *Solidification of Metals* by Ursula M. Martius.

Fundamentals of the Working of Metals. *G. Sachs. Interscience Publishers, New York, N. Y., 1954. Cloth. 166 pp. Price $4.75.*

Here is a textbook for students and practical engineers which offers in concise form the fundamental facts of working metals by forging, rolling, drawing, etc. Principles rather than individual fact are stressed.

Reports

Coatings On Polyester Laminates Effects of Resin Coating Methods and Other Variables on Physical Properties of Glass-Fabric Reinforced Polyesters. *B. M. Axilrod, J. E. Wier and J. Mandel, National Bureau of Standards, Aug. 1954. NACA RM*

Contents Noted

Reports

54G26, 22 pp, 6 tables. Available from the National Advisory Committee for Aeronautics, 1512 "H" St., N.W., Wash. 25, D. C. Effects of resin-coating methods on properties of glass-fabric laminates with three finishes and two polyester resins were investigated. Coating methods were roller, use of dilute resin solution, resin immersion, use of monomeric styrene, and vacuum impregnation. A normal high-temperature rapid cure and a moderate-temperature slow cure were used. Laminate preparation followed a statistical design to minimize uncontrollable variables. Tests included flexural strength both dry and after water immersion, specific gravity, resin content, and voids content.

Additives Lubricate Steel Effects of Chemically Active Additives on Boundary Lubrication of Steel by Silicones. *S. F. Murray and Robert L. Johnson, Aug. 1954. NACA TN 3257, 24 pp, diagrams, photographs, table. Available from the National Advisory Committee for Aeronautics, 1512 "H" St., N.W., Wash. 25, D.C.* Conventional chemically active additives and more active compounds such as peroxide did give effective lubrication. However, all the chemically active-type additives were inferior to the solvent-type additions such as the diesters previously studied.

UHF Materials Measurements of Materials with High Dielectric Constant and Conductivity at Ultrahigh Frequencies. *Herman P. Schwan and Kam Li, University of Pennsylvania, Moore School of Electrical Engineering and Dept. of Physical Medicine, Electromedical Laboratories, Philadelphia, Pa., 1953. PB 113997, 18 pp, diagrams, graphs. Available from Library of Congress, Publication Board Project, Wash. 25, D.C. Microfilm $2.00, Photocopy $2.75.* The purpose of this paper is to summarize how measurements of dielectric properties of material with high complex dielectric constant are performed to obtain accurate results throughout the frequency range from 100 to 1000 mc.

Wood Testing Non-Destructive Testing of Wood Laminates. Final Report. *S. V. Galginaitis, E. R. Bell, A. M. Fine, G. Auer, J. Roy, University of Louisville, Institute of Industrial Research, Louisville, Ky. PB 114022, 27pp, photographs, drawing, diagrams, graphs, tables. Available*

Contents Noted | Reports

from Library of Congress, Publication Board Project, Wash. 25, D.C. Microfilm $2.25, Photocopy $4.00.

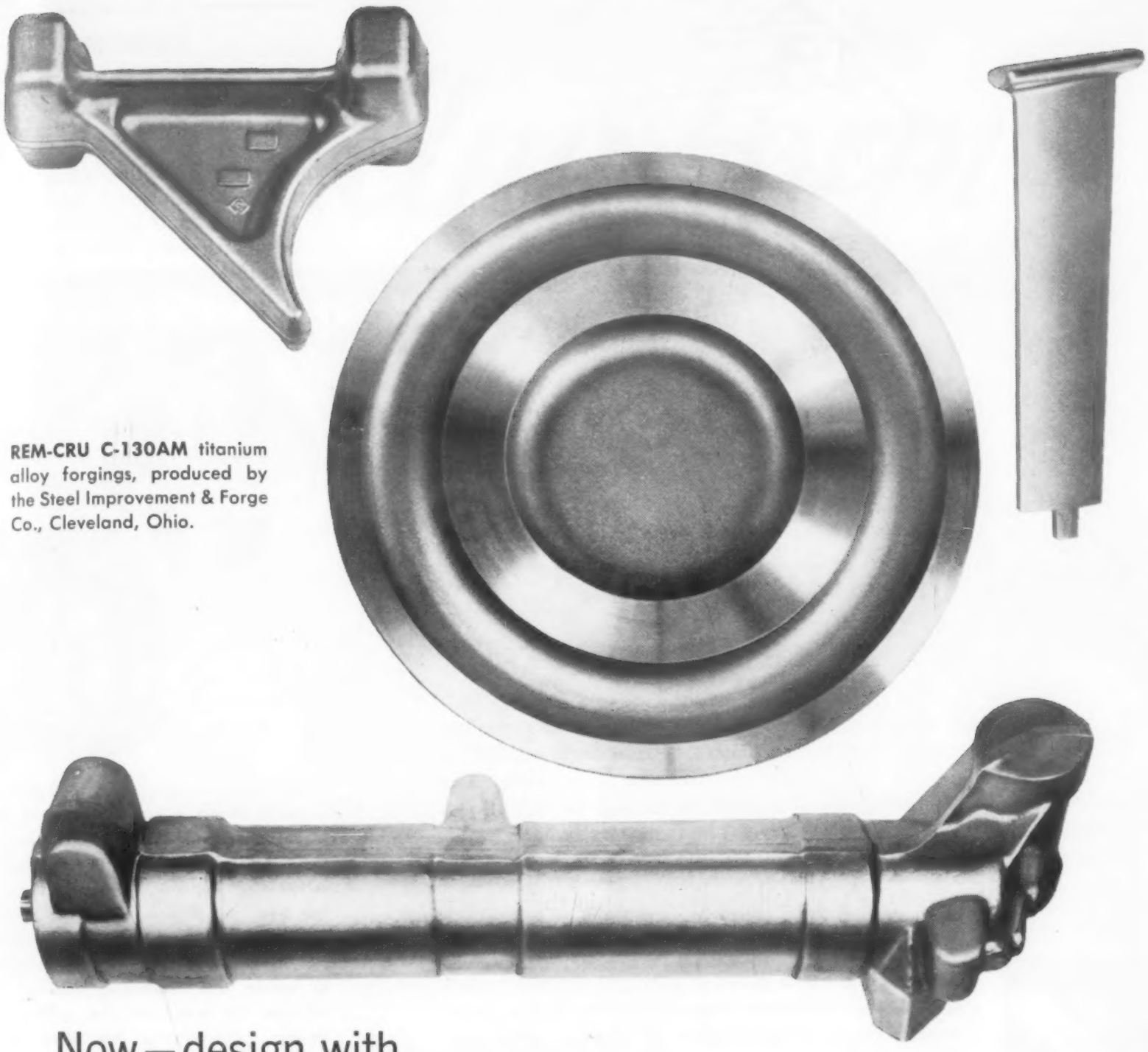
Industrial Films Selected Industrial Films: Refrigeration Equipment, A List and Description of Films Available to Business from Industrial, Commercial, and Government Sources. *U. S. Office of Technical Services, May 1954. PB 11382, 8pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Wash. 25, D.C. $.50.*

Beryllium Single Crystals Deformation of Beryllium Single Crystals at 25 C to 500 C. *H. T. Lee and R. M. Brick, University of Pennsylvania, Towne Scientific School, Dept. of Metallurgical Engineering, Sept. 1953. PB 114070, 103 pp, photographs, diagrams, graphs, tables. Available from Library of Congress, Publication Board Project, Wash. 25, D.C. Microfilm $4.75, Photocopy $14.00.* Part I includes experimental observations of the study. Part II consists of some crystallographic analyses regarding to twinning and slip.

Brazing Molybdenum Evaluation of Alloys for Vacuum Brazing of Sintered Wrought Molybdenum for Elevated-Temperature Applications. *Kenneth C. Dike, U. S. National Advisory Committee for Aeronautics, May 1954. PB 114262, 13 pp, photographs, diagrams, tables. Available from National Advisory Committee for Aeronautics, 1512 "H" St., N.W., Wash. 25, D.C.* The brazing characteristics of 28 alloys with liquids temperatures in the range 2000 to 2500 F, were established in a vacuum.

Strain Rate of Metals Influence of Temperature and Rate of Strain on the Properties of Metals in Torsion. *Clyde E. Work and Thomas J. Dolan, Illinois Engineering Experiment Station, Dept. of Theoretical and Applied Mechanics, Urbana, Ill., Nov. 1953. PB 114152, 107 pp, photographs, drawings, diagrams, graphs, tables. Available from Engineering Experiment Station, University of Illinois, Urbana, Ill. $1.00.*

Germanium Some Surface Effects on Germanium. *S. R. Morrison, Illinois Engineering Experiment Station, Electrical Engineering Research Laboratory, Urbana, Ill., Sept. 1953. PB 113921, 22 pp, graphs, table. Available from Engineering Experiment Station, University of Illinois, Urbana, Ill.*



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The advantages of REM-CRU titanium are so superior, you just can't afford to overlook them when designing new products. For down-to-earth suggestions on how to make the most profitable use of titanium, call a REM-CRU engineer *now*.

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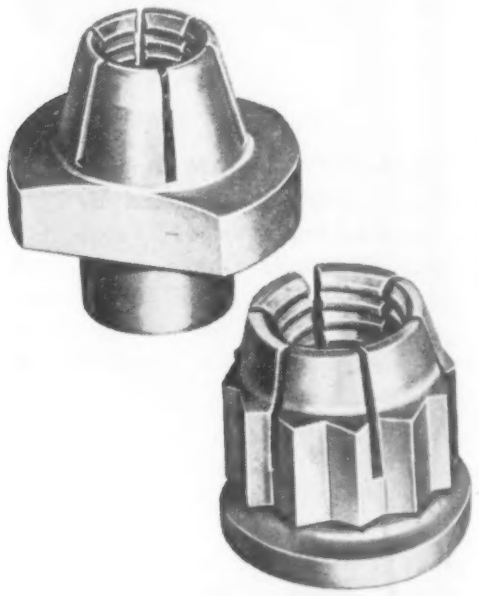
Correction

In the article "Fasteners for High Temperature Service", appearing on pages 104 to 106, September 1954, the captions and illustrations did not correspond. To correct this error, we are re-publishing below the fastener illustrations with their correct captions. The captions have been slightly shortened.—*The Editors*



To fasten components in the GETG-190 turbo-jet engine, a nut was required which would withstand seizure and vibration at temperatures of 1200 F. This called for a self-locking fastener of new design. On the basis of all-around performance, an 18% chromium-10% nickel steel stabilized with columbium and modified with selenium to obtain free machining qualities was selected. To overcome the galling tendencies, silver-plating was used. Shown are two modifications of the basic design adopted to meet specific requirements.

(Elastic Stop Nut Corp. of America)

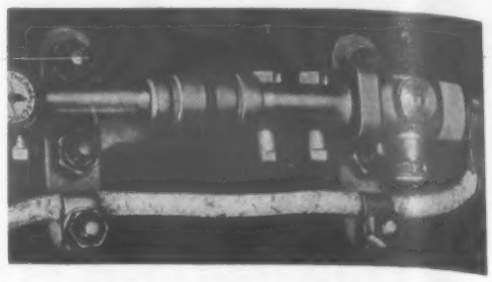
To assemble components at temperatures up to 1600 F where high frequency vibration is a factor a locknut was required which could be readily re-used. The nut is designed to reduce high stress concentration and torsional load in the first three threads and distribute the load over a greater number of threads. Locking occurs when the grooved washer is wrenched down against the work surface. (Note: Position of fastener as shown here is correct. In originally published article, fastener was shown up-side down.)

(Klincher Locknut Co.)

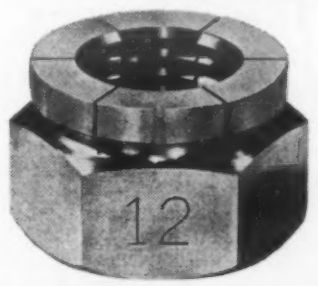
(Continued on page 192)

Correction . . .

continued from page 190



To fasten a safety switch to the afterburner of a jet engine, it was necessary that the screw head be within the afterburner and the locknut be close to the afterburner surface. In addition to withstanding temperatures of 1600 F, nuts were required to resist vibration but be capable of ready removal. Seizing and galling of the bolts was reduced by using a truncated, rather than a sharp thread crest and a rolled or ground finish. Metal to metal contact was prevented with a chromium oxide coating. The locknut designed for use in this application is a stabilized stainless steel two-piece nut consisting of a split, threaded core keyed into a hexagonal shell. *(Delron Co., Inc.)*



A locknut was required to withstand temperatures to 1200 F for applications in exhaust manifold systems, furnaces and firewall assemblies. The nut designed for this service was a stop nut as well as a locknut, that is, it locked at any point along the bolt or stud whether seated or not. Firm locking action even under vibration is provided by the slotted top, divided into six segments, which are closed in to make the locking collar smaller than the outside diameter of the companion bolt. The spring tension resulting when the nut is applied holds the locknut securely at any position on the bolt. To overcome seizure, the nut is silver-plated.
(Standard Pressed Steel Co.)

Coming in December

Next month M&M will present an unusual survey of a broad field of materials — the so-called "clad metals", "bimetals", "prefinished metals", and the many other types of metal laminates available. Look for M&M Manual No. 111.

Also: Plastics for Tooling, Brush Plated Coatings and Pickling Titanium.

news of | ENGINEERS COMPANIES SOCIETIES

News of Engineers

Robert G. Matters has been named assistant director of research, Allis-Chalmers Manufacturing Co.

•

John W. Bolton has retired as chief metallurgist and research director, Lunkenheimer Co. **Marvin L. Steinbuch,** assistant director of the Metallurgical Research & Testing Div., will succeed Mr. Bolton.

•

Harry T. Bellamy, Lindberg Engineering Co. ceramist, has been appointed as refractory technologist to the North Western Railway of Pakistan's new refractory manufacturing plant in Malakwal. Mr. Bellamy is being sent to Pakistan by Armour Research Foundation of Illinois Institute of Technology in connection with a Foundation project to advise in the building and operation of the plant under the Foreign Operations Administration's foreign aid program.

•

Richard K. Scales has been appointed general manager, Detroit Research Laboratories, Ethyl Corp., and Dr. **George F. Kirby, Jr.,** has been named general manager of research and engineering at the company's Baton Rouge plant.

•

Robert Zimmerman has been named chief staff engineer for the program planning and reporting group of the Weapon Systems Div., Radioplane Co., a subsidiary of Northrop Aircraft, Inc. **Jack Gearhart** has been named a senior project engineer.

•

W. L. Fabianic has been elected vice president in charge of research and quality control, and **P. K. Nichols** has been elected vice president in charge of operations, Laclede-Christy Co.

•

Dr. **Athelstan Spilhaus,** dean of the Institute of Technology, University of Minnesota, has been retained by Minneapolis-Honeywell Regulator Co. as a consultant in the fields of engineering and research.

•

Joseph P. Costigan, formerly operations manager, Alloy Rods Co.,

news of ENGINEERS

has been named works manager of American Machine & Foundry Co.'s Buffalo plant.

•

J. P. Coughlin, former manager of the Arc Welding Div., Westinghouse Electric Corp in Buffalo, has joined Eutectic Welding Alloys Corp. as assistant to the president.

•

J. Robert Pauline has been appointed vice president, Kellogg Div., American Brake Shoe Co.

•

Arthur E. Raymond, vice president in charge of engineering and director of Douglas Aircraft Co., Inc., has been named to receive the Spirit of St. Louis Medal. The award, which is administered by the Board on Honors, The American Society of Mechanical Engineers, is conferred for meritorious service in the advancement of aeronautics and was established by the citizens of St. Louis, Mo., 1929.

•

E. C. Rook has been appointed vice president and general manager, Blaw-Knox Equipment Div., Blaw-Knox Co. Mr. Rook, recently retired as a captain in the U. S. Navy, succeeds **G. L. Dirks,** who resigned.

•

Sidney Minault, formerly chief engineer, National Research Corp., has been promoted to works manager and is now responsible for both the production and engineering departments, of the company's Equipment Div.

•

Robert L. Bell, formerly superintendent of metals, Carboloy Dept., General Electric Co., has been appointed manager of manufacturing engineering.

•

Dr. Albert W. Meyer, in charge of U. S. Rubber Co.'s New Materials Dept. at Passaic, N. J., has been appointed to the newly-created position of director of exploratory research for Diamond Alkali Co. Other organization changes at Diamond Alkali Co. include the appointment of **C. C. Brumbaugh** as director of research, Atomic Energy, Alkali and Electrolytic Products.

•

Herman J. Schorle, formerly works manager, Bendix Aviation Corp. has joined Tobe Deutschmann Corp. as works manager.

•

Clarence G. Bieber has been appointed head of the Special Alloys

news of ENGINEERS

Section; **George R. Pease,** head of the Welding Section, and W. W. **Sellers,** head of the Electrochemical Section, Bayonne Research Laboratory, the International Nickel Co., Inc.

•

Dr. Rudolph Kluiber and **Eugene J. Kupchik** have joined Bakelite Co., a Division of Union Carbide and Carbon Corp. Their field will be fundamental research on polymers.

•

Lucas P. Hart, Jr., has been appointed manager of manufacturing for General Electric Co.'s Capacitor Dept. Mr. Hart, formerly manager of manufacturing facilities and engineering for the department, succeeds the late **J. T. Holleran.**

•

Dr. R. C. Gibson has been appointed assistant vice president, Parker Rust Proof Co. Announcement was also made of the promotion of **E. W. Richards,** formerly service manager, to the post of technical director. **R. I. Peterson,** formerly assistant service manager, will take over Mr. Richards' post.

•

W. Z. Friend has been appointed to succeed **F. L. LaQue** in charge of the Corrosion Engineering Section, the International Nickel Co., Inc. **Dr. T. P. May** and **H. T. Paterson** have been appointed technical manager and operational manager, respectively, of the "Kure Beach" Corrosion Testing Station near Wilmington, N. C.

•

G. R. Cuthbertson has been appointed production manager for the Tire Div., United States Rubber Co.

•

Joseph L. Nelson has been appointed design manager, Specialty Products Div., Edwin L. Wiegand Co.

•

Walter O. Lewin has been made general manager of the newly acquired Champion Div., Steel Improvement & Forge Co. **Deward H. Hardesty** has been appointed superintendent of the division.

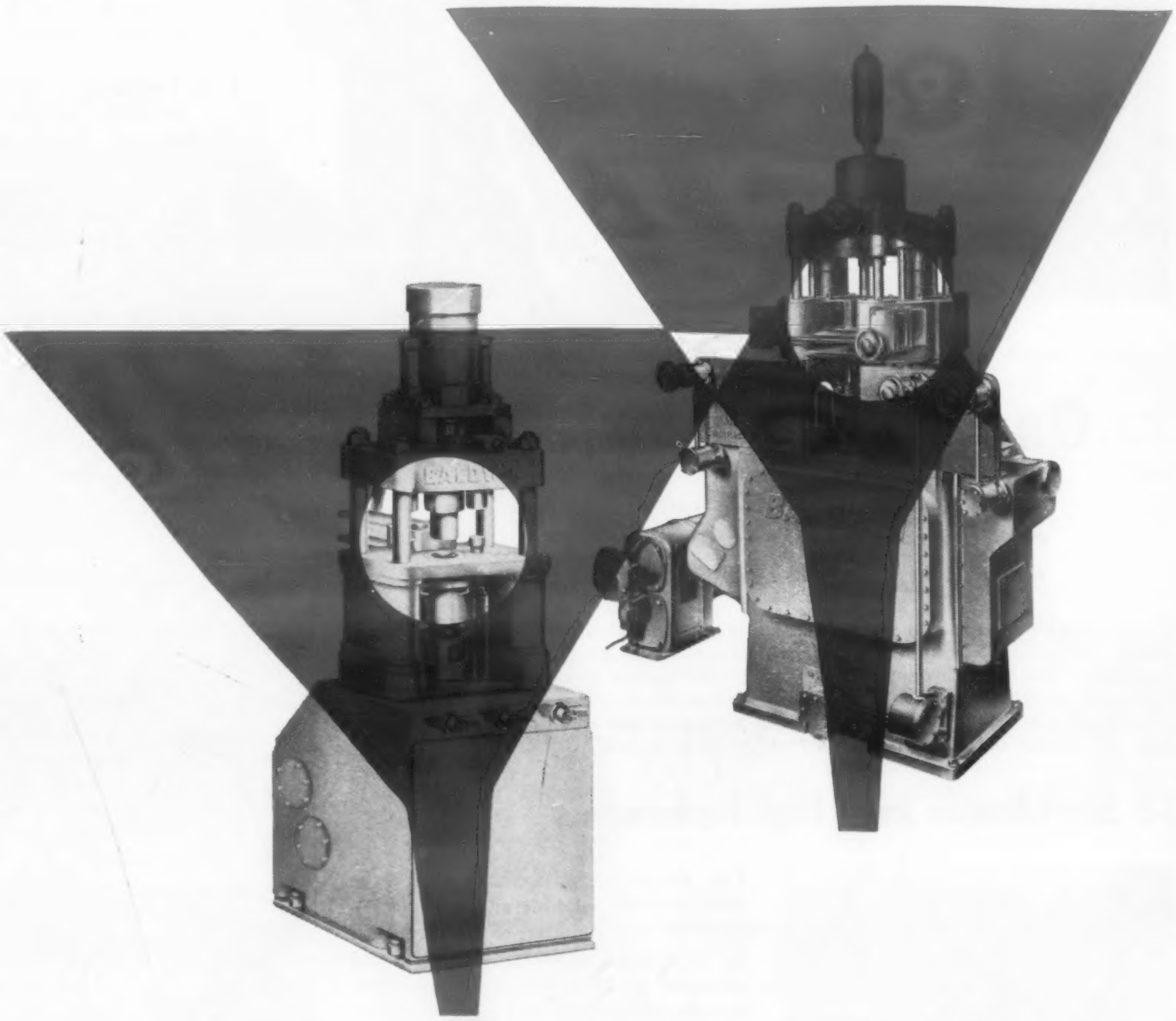
•

Walter F. Larson has been appointed chief engineer of the new hydraulic equipment dept., Sutton Engineering Co.

•

Norman Birch has been appointed vice president in charge of operations, **I. Eugene Cox** as vice president in charge of engineering and

PRECISE FILLING OF DIES *by new Baldwin powdered metal presses makes compacts more uniform . . .*



THEIR highly efficient shuttle type feeders enable Baldwin's new Model **"L" and Model "C"** powdered metal presses to compact parts much more uniformly. Air operated and cam controlled, this unique feeder moves from under a stationary hopper to a position over the die. It carries the same volume of material over the die cavity each time with a very smooth motion.

This shuttle is supported on guide rods with a spring loaded cutoff ring which prevents loss of material. Cleanline design of the feeder eliminates those recesses or projections that might keep the powder from filling the die cavity completely.

This is just one of the ways you'll benefit by specifying Baldwin Model "L" (50-ton) or Model "C" (100-ton) presses to meet the growing demand for powdered metal parts. These new presses are the very first designed specifically for use in compacting metal powders. Both feature sealed mechanisms, hydraulic heads, special fill adjustments, automatic lubrication and variable cycling.

For our new bulletins on "L" and "C" please write promptly to our Dept. 4723, Baldwin-Lima-Hamilton Corporation, Philadelphia 42, Pa.

BALDWIN-LIMA-HAMILTON

Philadelphia 42, Pa. • Offices in Principal Cities

For more information, turn to Reader Service Card, Circle No. 325

news of ENGINEERS

development and **Bernard Esarey** as works manager of the Meadville, Penna., plant, National Bearing Div., American Brake Shoe Co.

•

J. L. DeDiemar, former Convair design specialist, has been appointed chief engineer, Resdel Engineering Corp.

•

Henry C. Guhl, formerly manager of engineering for the Micarta Div., Westinghouse Electric Corp., has been named manager of process engineering by National Vulcanized Fibre Co.

•

Philip H. Rhodes, technical director, Clopay Corp., has announced his resignation in order to reenter the consulting field. Mr. Rhodes' new address will be 4354 Hamilton Ave., Cincinnati 23, Ohio.

•

John Cook, grinding department foreman, Norton Co., has retired after 43 years with the company.

•

John E. Fries, Jr. has been appointed chief metallurgist for the National Bearing Div., American Brake Shoe Co.

•

John J. Halvorsen has been appointed director of technical services for the Mills Plastic Pipe Div., Continental Can Co.

•

E. C. Graves, superintendent of fabricating, Carboloy Dept., General Electric Co., has been named superintendent of product manufacturing.

•

Dr. Stanley M. Davis has been named supervisor of the new identification and physical measurements laboratory of the analytical section, American Cyanamid Co.'s Bound Brook plant's Tecinical Dept. **Franklin C. Dexter** has been appointed special assistant to the manager of the analytical section and **Dr. Isaiah Von** was named a group leader in dyes development.

•

Edward R. Maddock has been appointed works manager of Worthington Corp.'s Decatur, Ala. works.

•

Robert B. Heppenstall, Jr. has been named general manager of the Bridgeport, Conn., plant of Heppenstall Co. to succeed the late **Alfred J. Porter.**

(News of Companies on page 200)

UNMATCHED
LUBRICANT CONTROL
conpor
gives less leakage, less friction, longer life, greater economy

Only* Conpor *gives you a complete range of porosity control

Conpor *is not* merely leather which has been surface-coated with an impervious elastomer. **Conpor** *is* a long-sought series of new and vastly superior materials for lubricant sealing, in which elastomer and leather are combined permanently to produce the exact degree of porosity and lubricity required. Lubrication of the sealing lip is controlled to give longer life and higher efficiency while objectionable leakage is minimized. **Conpor** *is not* completely impregnated.

Conpor sealing members are compatible with a wide variety of oils, hydraulic fluids, solvents, and gases. They remain flexible, heat stable, and fully operative for longer periods and at higher temperatures than any similar material. No other sealing material offers **Conpor's** outstanding advantages, long service life, and low cost.

Let Chicago Rawhide engineers show you how to solve your sealing problems at lower cost—with **Conpor**.

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CHICAGO RAWHIDE MANUFACTURING COMPANY

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Oil Seals: Shaft and end face seals for all types of lubricant retention and dirt exclusion • Sirvene (Synthetic rubber) diaphragms, boots, gaskets, and similar parts for critical operating conditions • Sirvis: Mechanical leather packings and related products.

For more information, turn to Reader Service Card, Circle No. 477

news of COMPANIES

Olin Mathieson Chemical Corp. has acquired a substantial interest in **Hunter Engineering Co.**

•

Newage International, Inc. has announced the opening of its new factory in Toronto, Newage (Canada) Ltd.

•

Minneapolis - Honeywell Regulator Co. has purchased the assets of **Heiland Research Corp.** The firm will be operated as a new Honeywell division.

•

Federal Pacific Electric Co. has acquired **Gardner Electric Manufacturing Co.**

•

Corrosion Services Inc., Tulsa, Okla., an organization devoted to the installation and servicing of corrosion control systems for industry, has been named distributor for **Dow** magnesium anodes for the protection of underground and underwater structures.

•

H. K. Porter Co., Inc. has acquired a substantial majority of the common stock of **Laclede-Christy Co.**

•

Pittsburgh Plate Glass Co. has started construction of its new $34,000,000 plate glass producing plant. Designed for straight line production, the plant will be nearly three-quarters of a mile in length.

•

Cooper Alloy Corp. is the new company name of Cooper Alloy Foundry Co. **American Cyanamid Co.'s** Research Div. has announced the organization of two new departments: the Basic Research Dept. and the Research Service Dept. Both are at the Stamford Research Laboratories.

•

New England Lacquer Co. has merged with **Chemical Products Corp.**

•

Ferro Corp. has completed a furnace modernization program for the **RCA Estate Appliance Corp.** range plant in Hamilton, Ohio.

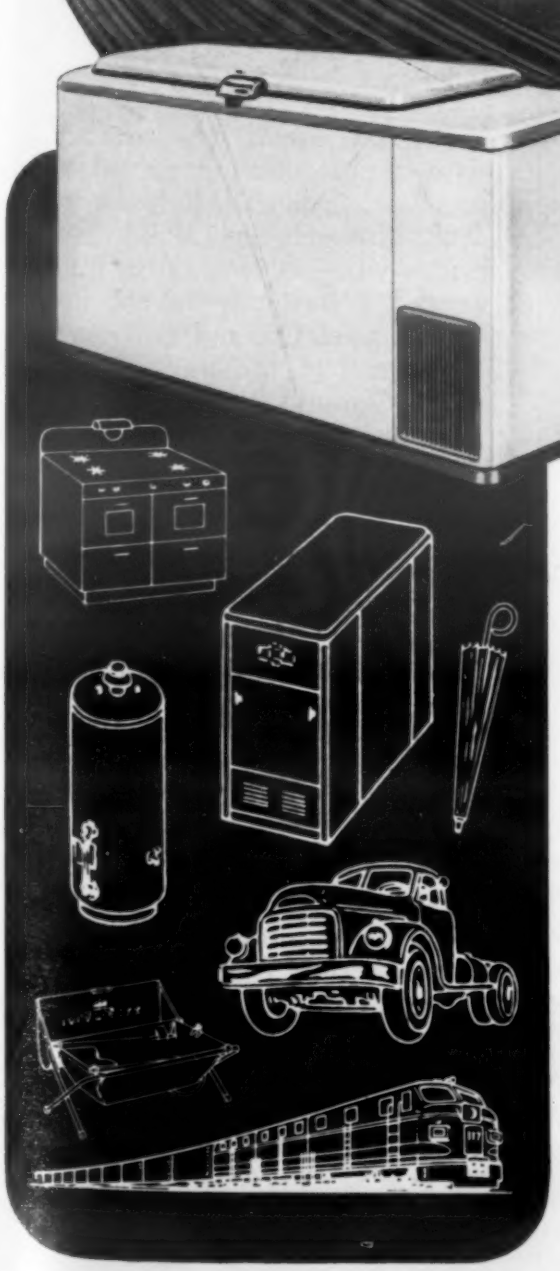
•

Kaiser Metal Products, Inc., has announced that its Aircraft Div. has been renamed Fleetwings Div. This division will embrace all aircraft and military manufacturing and development activities of the company.

•

(News of Societies on page 202)

The Tube Line That Rates a Buy-Line!



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news of | SOCIETIES

Investment Casting Institute recently held its second annual meeting in Chicago. Technical sessions included talks and discussion by nationally known authorities on such topics as: Proper Gating, Sprueing and Risering; Metal and Mold Temperatures; Melting Techniques; Heat Treatment, and Investments.

•

Franklin Institute has announced that a Francis J. Clamer Medal will be awarded to William Justin Kroll, Corvallis, Ore. The Institute honors Dr. Kroll "In consideration of his invention of a method adaptable to the large scale production of cold malleable commercially pure titanium and zirconium".

•

The **American Society of Mechanical Engineering** has announced that E. Q. Sylvester, executive vice president, Griffin Wheel Co., has been named to receive the Melville Prize Medal. The award is conferred annually for the best paper on a mechanical engineering subject presented for discussion and publication to the Society.

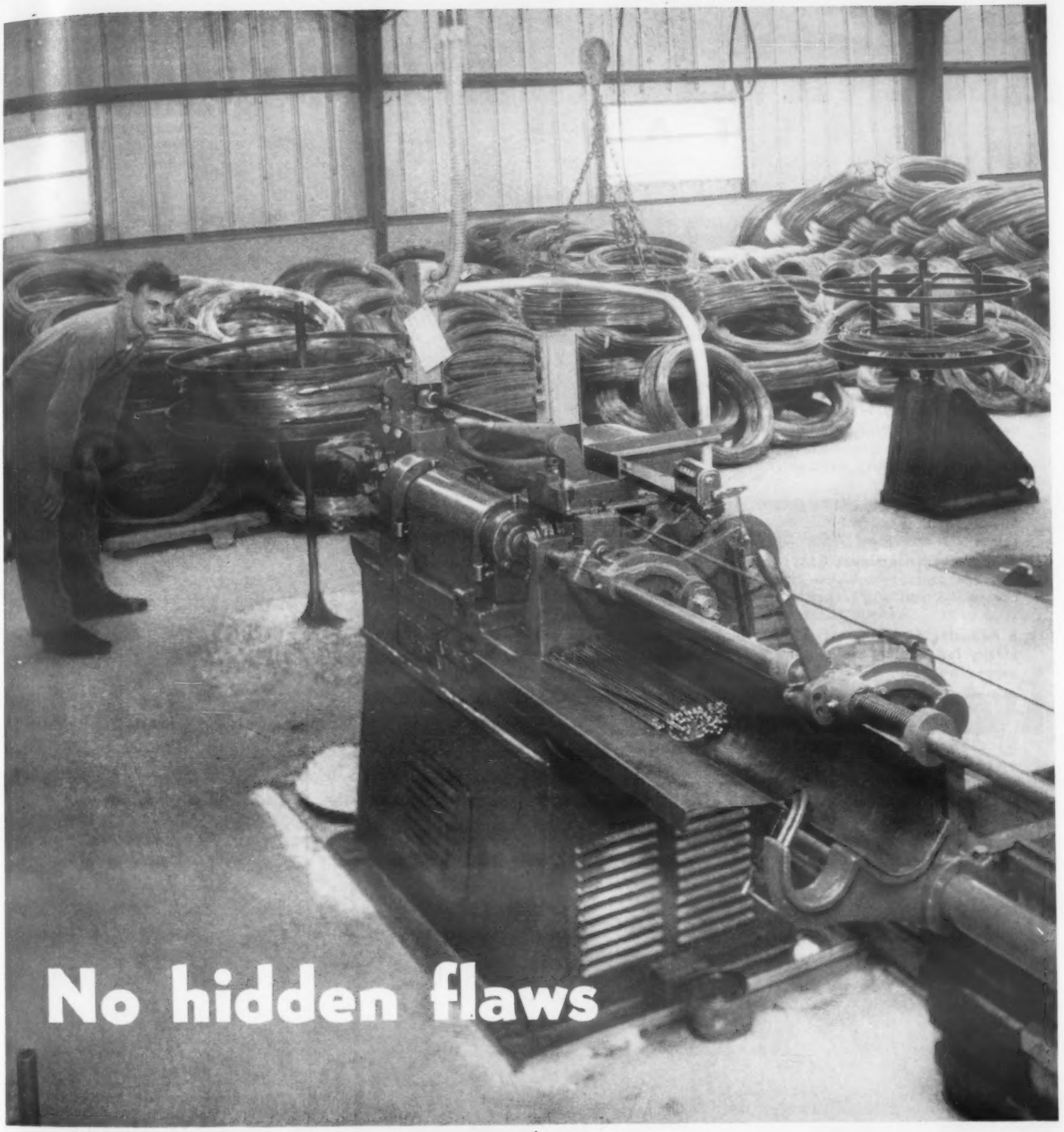
•

Pressed Metal Institute at its sixth annual meeting elected as its president, Samuel Morrison, president, Morrison Steel Products, Inc. Elected vice presidents of the Institute were: J. J. Boehm, president, Boehm Pressed Steel Co. and C. Glenwood Rose, president, Judson and Rose, Inc. W. B. Gemmill, treasurer, American Stamping Co., was elected secretary-treasurer.

•

American Society of Mechanical Engineers has announced that Walter A. Shewhart, research statistician with Bell Laboratories, has been named to receive the Holley Medal. This award, which is administered by the Society's Board on Honors, is conferred to "one who by some great and unique act of genius of an engineering nature has accomplished a great and timely public benefit". The Society has also announced that Emmett E. Day, associate professor of mechanical engineering, University of Washington, Seattle, has been named to receive the Pi Tau Sigma Gold Medal Award. The Medal is given annually to a young mechanical engineer for outstanding achievement in his field, within ten years following graduation from a regular four-year mechanical engineering course in an accredited American college or university.

(Meetings & Expositions on page 204)



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• For more information, turn to Reader Service Card, Circle No. 412

Meetings and Expositions

MAGNESIUM ASSOCIATION, annual meeting. St. Louis. Nov. 15-17, 1954.

AMERICAN STANDARDS ASSOCIATION, national conference. New York. Nov. 15-17, 1954.

AMERICAN GAS ASSOCIATION, operating section, organization meetings. New York. Nov. 15-18, 1954.

NATIONAL ASSOCIATION OF CORROSION ENGINEERS, Western Region, annual conference. Los Angeles. Nov. 18-19, 1954.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, annual meeting. New York. Nov. 28-Dec. 3, 1954.

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS, electric furnace steel conference. Pittsburgh. Dec. 1-4, 1954.

SOCIETY OF THE PLASTICS INDUSTRY, INC., Film Sheeting and Coated Fabrics Div. conference. New York. Dec. 7-8, 1954.

INSTITUTE OF THE AERONAUTICAL SCIENCES, INC., Wright Brothers Lecture. Washington, D. C. Dec. 17, 1954.

SOCIETY OF AUTOMOTIVE ENGINEERS, annual meeting. Detroit. Jan. 10-14, 1955.

INDUSTRIAL HEATING EQUIPMENT ASSOCIATION, INC., annual meeting. Detroit. Jan. 24-25, 1955.

SOCIETY OF THE PLASTICS INDUSTRY, INC., Reinforced Plastics Div. conference. Los Angeles. Feb. 8-10, 1955.

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS, annual meeting. Chicago. Feb. 14-17, 1955.

SOCIETY OF THE PLASTICS INDUSTRY CANADA, INC. Canadian conference. London, Ontario, Canada. Feb. 22-23, 1955.

SOCIETY OF AUTOMOTIVE ENGINEERS, passenger car, body and materials meeting. Detroit. March 1-3, 1955.

STEEL FOUNDERS' SOCIETY OF AMERICA, annual meeting. Chicago. March 14-15, 1955.

SOCIETY OF AUTOMOTIVE ENGINEERS, production meeting and forum. Cincinnati. March 14-16, 1955.

AMERICAN SOCIETY FOR METALS, Western metal congress and exposition. Los Angeles. March 28-April 1, 1955.

SOCIETY OF THE PLASTICS INDUSTRY, INC., Pacific Coast Section conference. Palm Springs. April 13-15, 1955.

AMERICAN SOCIETY OF LUBRICATION ENGINEERS, annual meeting and exhibit. Chicago. April 13-15, 1955.

SOCIETY OF AUTOMOTIVE ENGINEERS, aeronautic meeting, aeronautic production forum and aircraft engineering display. New York. April 18-21, 1955.

Basic Materials Conference and Exposition. Philadelphia. May 31-June 3, 1955.

News Digest

Army Barges . . . continued from page 13

find wide application in bonding flat and compound curved sandwiches for many uses. In working out methods for hand lay up of large vertical glass-fiber and polyester surfaces, the engineers found that conventional polyesters had a tendency to run, leaving higher areas resin-starved. The problem was solved by using the new thixotropic polyester resins. A mechanical impregnator is used to apply the resin to the cloth.

The barge is sectionalized for easy transportability into 15 separate assemblies. The sections were so designed that they have a maximum width of 10 ft in order to fall within railroad and highway limitatons and aircraft cargo hold dimensions. The barge is assembled in the water without special tools or skill.

Engineers on the project developed and tested several types of fasteners for use in conjunction with the sandwich material. They also developed a method for testing the adherence of the skin to the honeycomb, and ran many tests for resin suitability against aging and storage factors.

The dimensions of the assembled barge are: Length 51-ft beam 14 ft 8 in. It is powered by two 165-hp diesel engines, which give it a light speed of 14 mph.

The aft main hull section, containing the engine room, pilot house, crew's quarters, day tank, shafting and propellers is essentially of all-plastic construction. The hull and main superstructure are of sandwich construction, while the decks are of solid laminate. A particularly interesting use of plastic is found in the deck over the engine which is left in its natural translucent state to provide daylight illumination of the engines. Fuel tanks, water tanks, and even the crew's sink are made of plastic.

The prototype model of the barge was built by the Plastics Div. of the Englander Co. W. R. Chance and Associates, in cooperation with the Transportation Research & Development Command, designed the vessel.

(More News Digest on page 208)

CERTIFIED ZINC ALLOY PLAN
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AMERICAN DIE CASTING INSTITUTE

When casting requirements call for ZINC, call Monarch. Since 1938 Monarch has been die-casting zinc for a wide range of applications. Our experience gained in casting both aluminum and zinc allows us to offer unbiased engineering consultation toward adapting the best metal and method for your requirements. Monarch's practical approach to all types of casting and finishing methods has gained increasing acceptance by leading manufacturers—resulting in better end products at lower end cost.

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For more information, turn to Reader Service Card, Circle No. 443

News Digest

Research a Gamble Scientist Warns

Only one research project in twenty is brought to a financially successful conclusion, Dr. Gustav Egloff told members of the American Chemical Society in their recent New York meeting. Dr. Egloff, research director of the Universal Oil Products Co., Des Plaines, Ill., said one of the world's largest companies estimates that it spends four times as much on unsuccessful projects as it does on successful ones. He spoke at the society's symposium on costs in chemical development.

Expenditures Rise

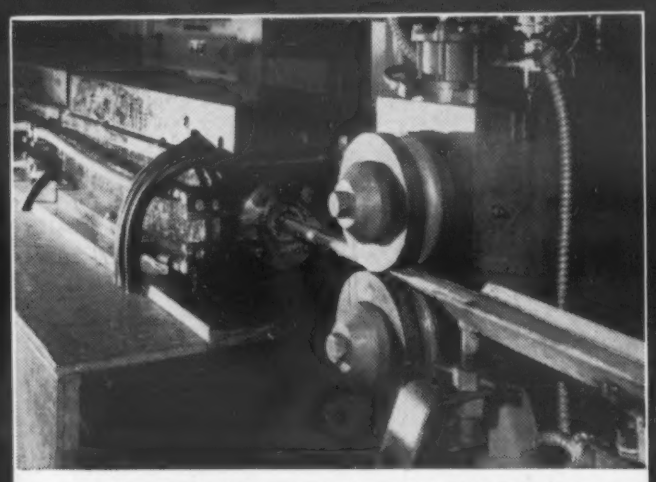
Nationwide expenditures for scientific and engineering research and development in 1952, the latest year for Labor Department figures are available, showed a 40% increase over 1949 and totaled about 3.75 billion dollars, Dr. Egloff said. More than two and one half billion of this was for work done in facilities owned or operated by private business, including 1.1 billion for work done for the government. Research performed in colleges and universities amounted to 420 million dollars. The government spent 800 million dollars for research in facilities which are its own.

Risky for Small Concerns

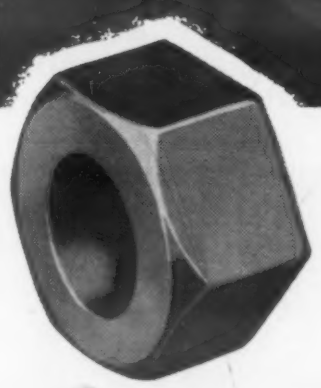
"Although it is generally agreed and statistically correct that research pays," Dr. Egloff said, "a smaller company considering starting a research department should bear in mind several factors. The chance that a specific research investigation will result in a large enough financial return to cover its costs is considerably less than even. The over-all profit from research results from an occasional project producing results of such value to more than offset the cost of a number of failures. A company initiating a research program should do so fully understanding that a considerable amount of money may be spent and much time may elapse before the venture is financially successful."

(More News on page 210)

4200 Nut Blanks Per Hour



Feed rolls push barstock through TOCCO Induction Coils to heat stock to 2350°F for forging.



with TOCCO* Induction Heating

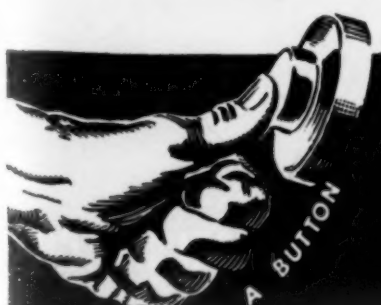
FASTER PRODUCTION—4200 nut blanks per hour—twice the output of a conventional hot punching machine—that's the result of Lamson & Sessions Company's new automatic production set up with TOCCO Induction Heating.

OTHER ADVANTAGES—TOCCO delivers exact temperatures (2350°F, plus or minus 25°) and delivers them so fast that scale has little time to form. Scale loss has been reduced to only about 1% for hot-rolled stock. TOCCO is clean and cool, fits right into the production line—no hauling to and from the heat-treat department—no unpleasant radiant heat to annoy workers.

HERE'S HOW IT WORKS—Steel bars up to 1½" diameter are fed through TOCCO Induction Coils. The first two coils, operating off a 300 kw, three kc TOCCO motor-generator set, preheat the rod. The third coil which operates from a TOCCO 250 kw 10 kc generator then boosts the rod to forging temperature. The hot rod then is fed to the special hot nut former (designed and built by NATIONAL MACHINERY CO.) which shears the rod to suitable lengths, forms the part and spits out the nut blank—ready for tapping.

In your search to find sound methods of increasing production, improving products and lowering costs, don't overlook TOCCO Induction Heating. If your products require heat treating, soldering, brazing or forging, it will pay you to investigate TOCCO for better, faster ways of producing them at lower unit costs.

THE OHIO CRANKSHAFT COMPANY



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For more information, turn to Reader Service Card, Circle No. 371

News Digest

GM Plans to Build Isotope Laboratory

General Motors Research Laboratory has announced plans to open a radioactive isotope research laboratory at its new Technical Center near Detroit.

According to Charles McCuen, general manager of General Motors Research Laboratories, the lab will be one of the largest privately owned industrial isotope facilities in the country. The laboratory work will be confined to isotope "tracer studies"—not research in nuclear physics.

In the chemical field, the company plans to study engine combustion and durability of paints and finishes. They hope to learn more about tool wear, design, materials, durability, and lubrication in the metals field.

Decision to go ahead with an independent isotope laboratory came as a result of a long series of design conferences with the AEC. From time to time during the past six years, personnel from the research laboratories have been attending AEC sponsored training courses at Oak Ridge for developing industrial uses of isotopes. The new lab will allow GM researchers to put their new techniques to work.

Sudbury Cobalt Now Flowing

As a result of improvements in refining techniques, the International Nickel Co. of Canada has initiated production of electrolytic cobalt at its Port Colborne Refinery. It is the first commercial production of cobalt in Canada.

The electrolytic cobalt will be particularly valuable for the manufacture of high purity alloys such as those used in turbojets. Heretofore, Inco's entire cobalt output has been marketed as oxides and salts produced at this Clydach, Wales, refinery.

The extra source of cobalt on the American continent is strategically significant, since the alloying metal has been critically scarce as a result of the need for high temperature resistant materials in aircraft and other military production.

The cobalt comes from the company's fabulous Sudbury District properties, which yield 13 different

NEW Viscasil

HIGH-VISCOSITY SILICONE FLUIDS

FOR NEW IDEAS IN PRODUCT DESIGN

Rate-measuring gyroscope, type K, courtesy Doelcam Corporation

Torsional vibration damper, courtesy Houdaille-Hershey Corporation

IDEAL FOR DAMPING!

Their flat viscosity-temperature curve, stability at elevated temperatures, nearly Newtonian viscosity characteristics and ability to resist breakdown under continual high-shearing stresses make G-E Viscasil fluids ideal for all kinds of viscous dampers.

EVALUATE G-E VISCASIL FLUIDS NOW!

Now is the time to begin *your* evaluations of these new fluids. They are destined to revolutionize many current design concepts. Through them *you* may achieve simplified designs, increased product reliability and performance—even *new* products never possible before. As you "imagineer" with them, remember to free your thinking from the design limitations imposed by conventional materials. *G-E Viscasil fluids often dictate the design!*

G-E silicones fit in your future

GENERAL ELECTRIC

General Electric's new Viscasil fluids offer tremendous potential for *new* product design and *present* product improvement because of this unusual combination of properties:

- **Relatively small change in viscosity over a wide temperature range**
- **Outstanding heat resistance**
- **Outstanding resistance to shear breakdown**
- **Unusual chemical inertness and stability**
- **Compressibility — far greater than other fluids**

Available in viscosities from 1,000 to 100,000 or more centistokes, these versatile silicone fluids are ideal for such applications as:

Torsional vibration dampers

Dashpot dampers **Shock absorbers**

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Electrical, release, pharmaceutical and cosmetic applications

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For more information, turn to Reader Service Card, Circle No. 493

News Digest

elements. While nickel is the principal product, the others are copper, palladium, platinum, ruthenium, iridium, rhodium, gold, silver, selenium and tellurium. Many of these metals have increased manyfold in industrial importance in the last few years.

Plastic Tooling Status Revealed

Plastic tooling for forming plastics has generated industry-wide interest as a result of its cost-cutting potential. At a recent meeting of the New York Chapter of the Society of Plastics Engineers, Dr. Walter Brenner summed up some recent innovations and warned that plastic tooling as it now stands is not a production panacea. Dr. Brenner, Chief Chemist at East Coast Aeronauticals, Inc., cautioned his engineering audience that plastic tooling should be used most judiciously and only where it can provide definite production advantages. He struck hard at the prevailing notion that unskilled employees can produce plastic tools. Not so at all, he claimed. Tooling is basically precision work, and where precision is required, so is competent labor. Saving payroll pennies can mean a loss compounded many times by an inaccurate tool.

Dr. Brenner revealed that his company uses epoxy, phenolic, and polyester molds for forming reinforced plastic and thermosetting plastic parts. They have had some success with heated matched plastic dies for forming reinforced plastic moldings. The heated dies are metal-filled epoxy resins with copper heating coils or low voltage resistance heating elements cast into the tool. The hot-die technique is far from perfected, however, and work is continuing on methods to secure uniform heat dispersion. The low heat conductivity of plastic dies is, of course, the major difficulty in hot die work.

Stresses Proper Resin Use

A second speaker at the SPE meeting, Dr. R. Nelb from Naugatuck Chemical, stressed the need for imaginative applications of the resins now available, and pointed out the vital importance of proper engineering in all applications.

Dr. Nelb pointed out that the great period of new resin synthesis has abated, and now the plastics industry

News Digest

is entering a period of applicational refinement which will result in properly engineered uses for the resins we now have. At this stage in the growth of the plastics industry the emphasis is on resin refinement and modification rather than on radically new discoveries. Compounding resins to gain specific properties and standardization of techniques are the two most promising and challenging directions for plastics engineering, Nelb claimed. He said that since plastics have emerged as unique materials with unique properties, cost reduction should not be the prime consideration in using plastics. Rather, they should be selected on the same basis as all engineering materials and not as substitute materials.

In reply to questions from the floor, Nelb commented that the radiation cure of plastics is promising, but much work is still ahead before any economic appraisal can be made. Radio frequency heating for shorter cure times is of more immediate interest as a substitute for oven cure.

Columbium-Steel Welding Approved

The American Society of Mechanical Engineers recently approved the use of Carpenter Stainless No. 20 Cb plates, pipe, tubing, bars and forgings in welded construction.

According to a report of the ASME Boiler Code Committee, the alloy may be used in the construction of welded pressure vessels provided certain specifications and fabricating procedures are met. Nine such requirements are set forth in the study, designated ASME Case 1188.

The No. 20 Cb grade has been formluated specifically for those applications which involve welding during fabrication, and for those in which the parts must be placed in service in the as-welded condition. The addition of Columbium to the original Stainless No. 20 alloy minimizes the precipitation of carbides during hot working. This permits use of the welding process in fabricating equipment too large for subsequent annealing.

Stainless No. 20 Cb can be welded by any of the standard electric arc and resistance welding processes. Oxyacetylene welding is not recommended. Sound weld deposits can be obtained by using the welding tech-

How Hot can a Jet Get?

Whoooosshh! Jet engines generate a powerful amount of heat . . . heat which, uncontrolled in flight, would cause disastrous metallurgical distortions within the delicately balanced engine. So the problem is . . . or rather *was* . . . how to provide a dependably accurate means of measuring exhaust temperatures so that the pilot might have control over how hot his jets get.

And the answer? Special wiring harnesses running from engine to instrument panel . . . harnesses now made exclusively with Hoskins Chromel-Alumel thermocouple alloys.

Yes, wherever durability and accuracy are required in a thermocouple . . . whether for jet engines or industrial furnaces . . . you'll find Chromel-Alumel *right* for the job. Extremely durable . . . highly resistant to heat, corrosion, oxidation . . . guaranteed to register true temperature-E.M.F. values within specified close limits.

That's only part of Hoskins' product picture, though. Other specialized quality-controlled alloys developed and produced by Hoskins include: Alloy 785 for brazing belts; Alloy 717 for facing engine valves; special alloys for spark plug electrodes; Alloy 502 for heat resistant mechanical applications. And, of course, there's Hoskins CHROMEL . . . the *original* nickel-chromium resistance alloy used as heating elements and cold resistors in countless different products.

Heating elements made of Hoskins Chromel deliver full-rated power throughout their long and useful life.

Sparks fly better, last longer in today's spark plugs . . . thanks to Hoskins' spark plug electrode alloys.

Hot stuff for hot jobs! Hoskins Alloy 502 is ideally suited to many mechanical-structural applications.

Chromel® NICKEL CHROMIUM WIRE

HOSKINS

MANUFACTURING COMPANY

4445 LAWTON AVENUE, DETROIT 2, MICHIGAN

For more information, turn to Reader Service Card, Circle No. 403

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niques generally recommended for the fully austenitic steels. No special methods are required.

Typical applications for the alloy include mixing tanks, heat exchangers, process piping, bubble caps, metal cleaning and pickling tanks, spray pickle equipment, etc. The findings of the ASME are expected to further widen the applications for this steel.

Carpenter No. 20 Cb is a relatively new, super-corrosion resistant steel distributed in the forms of sheet, plate, pipe, tubing and bar by The Carpenter Steel Company's Alloy Tube Division, Union, N. J. Carpenter No. 20 without Columbium is available in bar, wire, strip and billet forms from the company's main plant in Reading, Pa.

Armour Sponsors Industrial Reactor

The first nuclear reactor for industrial research will be established at Armour Research Foundation of Illinois Institute of Technology, Chicago, Dr. Haldon A. Leedy, Foundation director, disclosed. By offering direct benefits to industry through a new research tool, the proposed reactor promises to be a major advance in the technology of the Chicago area, Leedy said.

Plans for the reactor—or "atomic pile"—are being submitted to the Atomic Energy Commission for consideration of the design, building plans, and schedule of operation. Chicago area industries will join the Foundation in financing the reactor and associated equipment, which will cost approximately $500,000. The reactor will be housed in a new 8000-sq ft building on the Illinois Tech campus.

The proposed reactor, designed for 50,000 w, is specifically a highly flexible neutron and gamma source, and is not intended for research on reactors themselves or for the generation of electrical power, according to Dr. Richard F. Humphreys, manager of the physics research department, who is director of the project.

The reactor will permit investigations into such fields as: sterilization of foods and drugs; high polymer studies of the structure of plastics, rubber and similar materials; glass and ceramics; wear and friction stud-

The mechanical brain of a Burroughs Corporation business machine cannot afford mistakes . . . every number must print in perfect alignment and be clearly legible. Helping Burroughs provide this unerring accuracy are radially cored die cast print wheels containing the numbers. These small print wheels, requiring machine tool precision and close tolerances, are made on KUX die casting machines. KUX machines were chosen because they can be depended on for casting parts of exacting dimensions with fine detail. Burroughs says production of print wheels has increased, "AND A BETTER PRODUCT IS OFFERED MORE ECONOMICALLY."

The wheels are cast on the Model K-7 vertical type center shot machine which is specifically designed for production of castings with inserts. Like the Model K-5, left below, both machines are massively built to withstand the high pressures required to produce at high speeds small, solid, dense castings having hardware quality finishes. Write for detailed specifications.

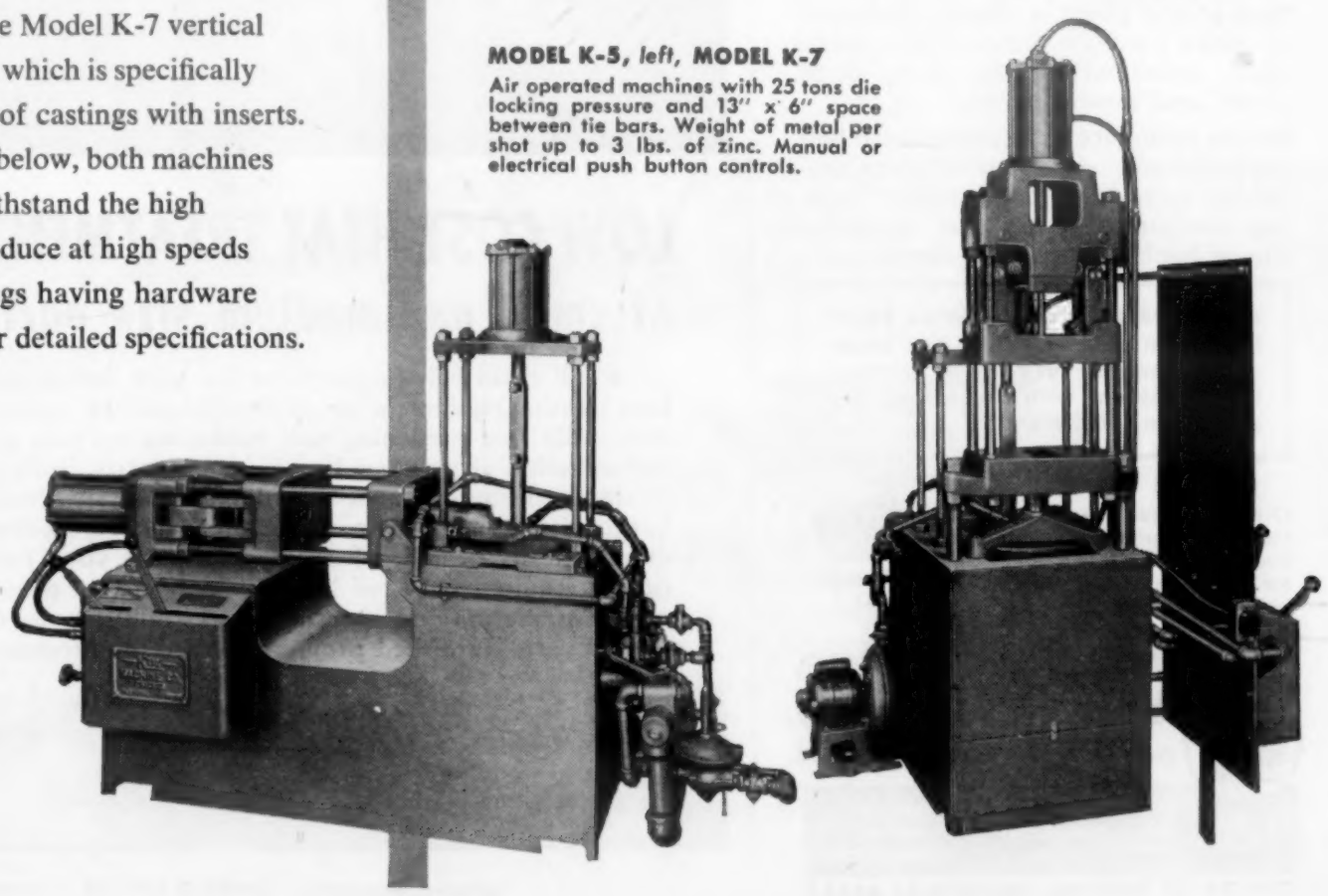
Kux
MACHINE COMPANY
6725 Ridge Avenue
Chicago 26, Ill.

EVERY NUMBER LEGIBLE
because of die cast print wheels
...SO

Burroughs chose Kux die casting machines

for production of these finely detailed parts

MODEL K-5, *left*, MODEL K-7
Air operated machines with 25 tons die locking pressure and 13" x 6" space between tie bars. Weight of metal per shot up to 3 lbs. of zinc. Manual or electrical push button controls.



* For more information, turn to Reader Service Card, Circle No. 362

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ies; the development of metals and alloys; and medical techniques for diagnoses and therapy.

At present, there is only one reactor not devoted to AEC work—a 10,000-w reactor at North Carolina State college. At least three more are being planned for educational and college research, but the Armour Research Foundation reactor is the first directed toward industrial research.

"Sponsored research will be subject to no security classification, no competition from military applications, no secrecy of any kind other than that called for in the protection of the individual sponsor's programs," Humphreys said.

Fuel for the reactor will be obtained from the Atomic Energy Commission on "extended loan," as required by law. The fuel will be granted only after careful inspection by the AEC.

Armour Research Foundation will assume about one-third of the investment. Industries in the Chicago area are being invited to participate in the construction of the facility with subscriptions of $20,000, for which they will receive many benefits.

Humphreys explained that the reactor will make possible: 1. production of short-lived radioisotopes that would be impractical to procure from distant government laboratories such as Oak Ridge; 2. neutron activation, a new and powerful technique used for the most sensitive chemical analysis now known (by this method, wear studies, non-destruction testing, and other difficult studies become possible); 3. neutron diffraction for use in structure analysis that exceeds standard x-ray techniques; 4. radiation-induced effects in plastics, glasses, organic systems, and metallic alloys; 5. studies on effects of radiation on biological and chemical systems.

An extensive research program will be conducted by the Foundation on problems of specific interest to the participating industries. Results of this research, including any inventions that may arise, will be made available to the participants.

A SPECIAL REPORT ON PROTECTIVE FINISHES FOR ALUMINUM

Most aluminum producers and fabricators are well aware of the superiority of chemical finishes over anodizing for the protection of aluminum from corrosion. Naturally, then, there is a running battle for acceptance among the leading producers of the protective chemical finishes.

That's why, here at Allied, we have always studied your needs with regard to both our own and competitive processes. We're constantly trying to produce new and better finishes because we believe there's always room for improvement . . . even to our own products. Some years ago this policy led to the introduction of a process, long in development, that offered you a way to overcome anodizing's obvious technical complications . . . Iridite #14. This finish was far easier to use than anodizing, yet provided comparable, if not superior, quality. And, its cost was much less than anodizing.

But other finishes offering similar advantages over anodizing have entered the market. So . . . the current battle for acceptance. By any cost comparison Iridite #14 is the most economical. However, corrosion tests by users show contradictory results as to performance from Iridite #14 and other leading protective finishes for aluminum. Most tests show Iridite #14 superior, but some do not. The margin of difference, however, is always small. The truth is that all have proved good. However, our laboratory research indicated that still further improvements could be made.

That knowledge . . . plus our aim to give you even better protection and maintain the leadership of the industry, is exactly why Allied Development Engineers have been working for long years to develop a better finish than any of those now available, including our own Iridite #14.

Now the new finish is ready for you. It's called Iridite #14-2 (Al-Coat).

From a performance standpoint, Iridite #14-2 gives you two important advantages in the protective finishing of aluminum.

FIRST: in its fully colored brown film stage it provides corrosion resistance decidedly superior to previous processes.

SECOND: the basic brown film can be hot water bleached to produce a clear-type film with protection heretofore unobtainable from clear-type chemical finishes.

From an operating standpoint, new Iridite #14-2 gives you three important advantages.

FIRST: it provides consistently higher corrosion resistance for different aluminum alloys treated in the same bath.

SECOND: it provides a more uniform appearance for parts of different alloys and with varied surface finishes before treatment.

THIRD: its operating and technical characteristics are superior to those of other processes.

If you are using or planning to use a chemical finish for aluminum, you should have full details on new Iridite #14-2. Write us or send samples for free test processing. Or, for more immediate advice, call your Iridite Field Engineer. He's listed under "Plating Supplies" in your classified telephone book. - - - ALLIED RESEARCH PRODUCTS, INC., 4004-06 EAST MONUMENT STREET, BALTIMORE 5, MARYLAND.

P. S. Even new Iridite #14-2 will be constantly measured against both your needs and competitive processes to make sure you get the best possible, most economical finish for your product that man and the laboratory can develop.

(Adv.)